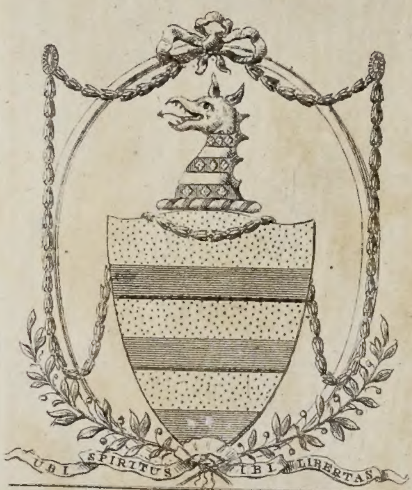
2 vols.
1st Edition Fine copy
Frontispiece + 62 plates
Rare.



W^m. Constable Esq^r.
F.R.S. & F.A.S.

2 vols

60 fldg plates.

m E

Mr Paumer an Ingenious Mechanick, was originally a Smith, but by his conversation with Mr Barlow (a Priest in Lanckishire, who first found out the fire Ingin and the repeating movement in watches and Clocks) he became ingenious in Mechanicks: but by misfortune marrying a wanton wife he took to sotting, drawing & drinking, to the grief of his friends & ingenious and being imploy'd by me in convaying water to my house he very gratefully left me as a Legacy these two volumes.

2 vols.
front & 61 plts (60 fld)
1st Skaved
a little offsetting

Oklahoma p.479

2 v.
$1000-

Frontispiece.

J. Devoto Inv.t Toms sculp.

Labuntur altis interim ripis aquæ —

Fontesque lymphis obstrepunt manantibus. Hor.

AN INTRODUCTION TO A GENERAL SYSTEM OF *Hydroſtaticks* and *Hydraulicks*, PHILOSOPHICAL and PRACTICAL.

WHEREIN

The moſt reaſonable and advantageous METHODS of raiſing and conducting Water, for the watering Noblemens and Gentlemens Seats, Buildings, Gardens, *&c.* are carefully (and in a Manner not yet publiſh'd in any Language) laid down.

CONTAINING IN GENERAL

A Phyſico-mechanical Enquiry into the Original and Riſe of SPRINGS; and of all the Hypotheſes relating thereto; as alſo the Principles of Water-works, and the Draughts and Deſcriptions of ſome of the beſt Engines for raiſing and diſtributing WATER, for the Supply of Country Seats, Cities, Towns corporate, *&c.*

Deduc'd from the Theory of *Archimedes*, *Gallileo*, *Torricelli*, *Boyle*, *Wallis*, *Plot*, *Hook*, *Marriotte*, *Deſaguliers*, *Derham*, *Hawksbee*, and others.

Reduc'd to Practice by *Vitruvius*, *Bockler*, *de Caus*, and other Architects amongſt the ancient *Romans*, *Italians*, *French*, *Flemmings*, and *Dutch*, and much improv'd by later *Practice* and *Experience*.

Illuſtrated and Explain'd by Sixty Copper Cuts, done by the beſt Hands, of the *Principles* which tend to the Explanation of the whole, and of rural Groteſque, and cheap Deſigns for Reſervoirs, Cataracts and Caſcades of WATER, Canals, Baſins, Fountains, *&c.* Collected from the beſt of the *Italian* and *French* Deſigns (together with ſome new ones of the Author's own Invention) few of which have ever appear'd in Books of Hydroſtaticks, *&c.*

In Two VOLUMES.

By *STEPHEN SWITZER.*

Sunt quippe (Hydroſtaticæ) *artis theoremata & problemata maximam partem genuina & pulchella ſoboles rationis circa argumenta attente penſitata rite ſe exercentis.* —— *Etenim complura ſunt, non ex familiaribus moda ſua, & abſtruſioribus naturæ Phænominis quæ nunquan Capientur penitus neque Explicabuntur dilucide ab iis qui hoſpites ſunt in Hydroſtaticis; a quorum Principiis pendent,* &c. Boyle's Paradox. Hydroſtat. Præfat.

LONDON:

Printed for T. ASTLEY, at the *Roſe*, S. AUSTEN, at the *Angel* in St. *Paul's* Church-Yard; and L. GILLIVER, at *Homer's* Head againſt St. *Dunſtan's* Church, *Fleetſtreet*. M.DCC.XXIX.

TO THE

RIGHT HONOURABLE

ALGERNOON, Earl of *Hertford*,

Baron Piercy, Beauchamp, *&c. Lord Lieutenant and* Custos Rotulorum *of the County of* Sussex, Custos Rotulorum *of the County of* Wilts, *Brigadier General of his Majesty's Forces, and Captain of the Second Troop of Horse-Guards.*

MY LORD,

WITH an Addreſs proportionate to the Honour and Dignity of thoſe two illuſtrious Families, from which your Lordſhip has deduced your high Birth, I preſent this Volume of *Hydroſtaticks* and *Hydraulicks* to your Patronage and Protection, depending upon two of the moſt valuable Epithets in humane Nature, *Your Affection to Arts and Sciences, and Benevolence to Mankind*: From both of which I am taught to hope you will encourage whatever tends to the Improvement of Mathematical and Philoſophical Knowledge, and excuſe

the Preſumption of one, who places your Lordſhip's Favour and Friendſhip among the greateſt Felicities of his Life.

If the low Eſtate, and Unworthineſs of the Author, ſhould be any Objection to the Succeſs of this Undertaking, the Uſefulneſs of the Subject will (it is humbly hoped) ſufficiently atone for it, eſpecially if handled in a Manner ſuitable to the Nobleneſs of it. The Hiſtory of Fluids being coeval with the World, and the moſt early Dawnings of Time it ſelf; and upon the Ceſſation of which, Nature, with all her numerous Offſpring, muſt neceſſarily recede and ſhrink back into its primary State (if I may ſo call it) of Non-entity and Annihilation, the Fluctuation of Fluids, the Elaſticity, Claſhing, and Receſſion of aerial and corpuſcular Atoms, and minute Particles of Matter, conſiſting, as it does, of one of the greateſt of her Laws, Motion (oppoſite to Stagnation and Reſt) being the Machine by which ſhe works all her Effects.

And as the Theory of Fluids contains in it the greateſt Scope of *Phyſico*-Mechanical and Philoſophical Reaſoning of any in Nature, and ſo of great Uſe to the moral and inquiſitive Reader; ſo alſo the Practice of it, in raiſing and conducting Water, is no leſs uſeful to the induſtrious and buſy Artiſan and Mechanick, in the Beautifying and Embelliſhment of a Country Seat, Water being, if I may be indulged the Liberty of ſuch an Expreſſion, *the very Life and Soul of a Garden*; the wafting of Trees, the warbling of Birds, the *mugituſque Boûm*, being ſubmiſſive Beauties, when put into Competition with the murmuring of Streams, and Cadence of Water.

It will not be to my Purpoſe, my Lord, nor ſhall I preſume to enter into the Diſcuſſion of a Point long held in Debate, between the Advocates *pro* and *con*, which of the Water-works were the moſt noble, thoſe of *Italy*, or thoſe of *France*, leaving that to the Deciſion of your Lordſhip, and thoſe ingenious Noblemen and Gentlemen of the *Britiſh* Nation, who are ſo impartial Judges of whatever is Natural, Noble and Polite; but thus far it appears by the Prints brought from thence, as well as from the Opinion of one of the greateſt Genius's of this Age, *That the Water-works of* Italy *are generally more natural, than thoſe of* France, *or contriv'd more agreeable to it; and that if the* French *do ſurpaſs them at preſent in their Gardens and Water-works, it is rather owing to the Greatneſs of their Riches, than the Excellence of their Taſte.*

I know, my Lord, how diſagreeable it will be to your Lordſhip, for me to expatiate on your Lordſhip's Character, either in publick or private Life, or at a Hiſtory of thoſe Noble Families from which you are deſcended (how juſt ſoever my Theme is); and I am the more unwilling to attempt it, leſt the Deſcription ſhould fall ſhort of the Subject, and the Picture ſuffer by the imperfect Shadows of ſo unmaſterly a Hand; but as the moſt humble Cottager can't but look with chearfulneſs on the cheriſhing Influences of a benign Sun; ſo, my Lord, I cannot without great Violence to my ſelf, finiſh this Epiſtle, without thoſe humble and ſincere Offerings of Gratitude and Thanks for a Friendſhip, which is much more owing to your Lordſhip's kind Diſpoſition, than to my Merit. Others look only upon thoſe whom Fortune, or the Favour of the Great, riſe

up

up to the Pinacles of Honour or Preferment; but your Lordſhip's good Nature overlooks that, and is the Cauſe that you extend your Notice to one in the loweſt State of Life, and who can make no other Return, than that of Gratitude and Reſpect.

If a ſincere Friendſhip and good Nature, a benevolent and candid Deportment to all about you, be the true Characteriſticks of a Gentleman of Humanity and Honour, well may I apply what the Hiſtorian ſays of one of the moſt beloved Patrons of Antiquity; *What Citizen? which of your Neighbours or Servants have you made uneaſy? Which of your Friends or Family is it that you have anywiſe injur'd or diſoblig'd?* Well would it be for Families and Eſtates in particular, as well as for the Peace of Society and the World in general, were thoſe Patterns of frugal, ſocial, and conjugal Virtues, of which your Lordſhip is ſo conſpicuous an Example, more prevalent and extenſive.

That theſe Gifts, the greateſt and happieſt which Omnipotence can confer on ſublunary Beings, may be tranſmitted to your Poſterity; and that the Illuſtrious Family of which your Lordſhip is ſo benevolent an Ornament, may be continued down in a direct Series, to the lateſt date of Time, is the ſincere Wiſh of,

My Lord,

Your Lordſhip's Moſt Obedient

Humble Servant,

Stephen Switzer.

THE

PREFACE.

EVEN as *Paradiſe* itſelf, tho' of Divine Appointment, muſt have been deem'd an immodel'd and imperfect Plan, had it not been water'd by the ſame all-powerful Hand which firſt made it; ſo never can our Gardens and Fields (the neareſt Epitomy and Reſemblance of that happy and bleſſed Place to be met with here below) be ſaid to be any way perfect or capable of ſubſiſting without it.

THE entire want of Water that is in ſome, and the ill Uſe, or little Management of it, which is to be found in other Places, are, I humbly hope, ſufficient to excuſe me from making any Apology for my preſuming to attempt at the undertaking of a Syſtem, the Steps

of which ſo few have trod before me, and which I have with much Care and Pains drawn together, for the Improvement of theſe and future Times.

It were indeed to be wiſhed, that ſome more able Hand, and who had more leiſure than I have, would have undertaken ſo uſeful a Work as this is, which has not (at leaſt that I know of) been drawn together into a Syſtem in any one Language whatſoever, but lies ſcattered up and down in Fragments and broken Pieces of Literature; on which Account I have adventured to throw in my Mite into this almoſt inexhauſtible Treaſury; which will, 'tis humbly hop'd, at leaſt, have this good Effect, as to excite ſome more knowing Pen to perfect what I have thus willingly begun

It is not at all to be doubted, but this, as well as many other Works, which are produc'd for the Publick Good, will meet with its Disfavourers, as well as thoſe who, out of a Value for the Improvements and Good of their Country, are willing to encourage all the Eſſays that are tending that Way, let them come from what Hand they will: To ſuch therefore I have little to ſay; but proceed, after this ſhort Introduction, to what is more generally intended in this Work, *viz.* The *propereſt Methods of raiſing and diſtributing Water for the Uſe of Country Seats, Towns Corporate*, &c.

It muſt be own'd, that the vaſt Expence which attends the raiſing up and conveying Water for the Embelliſhment and Watering of Noblemens and Gentlemens Seats, is one great Reaſon, that ſuch Works are not oftener undertook and perfected than they are, the

Expence

Expence of piping of Drains, *&c.* being ſometimes with Reaſon, (tho' at others with no Reaſon at all) an Intimidation to their Owners from conducting the Water thereto; not being able of themſelves, nor having the Convenience of any about them to calculate the real Expence that attends it: And this has been another Reaſon which has induc'd me to the following Eſſay, wherein I have, with as great Plainneſs as poſſible, ſet down the ſeveral Methods by which Water may be conveyed, becauſe I have obſerved, that this being often left to thoſe, (whoſe Buſineſs being rather to conſult their own, than the Intereſt of thoſe who employ them) have gone on in their own Way, tho' there are Ways much nearer, which has at laſt grown to an Expence ſo great, as to deter the Owner from perfecting what he had thus injudiciouſly, and perhaps without any Conſideration at all, begun.

Nor have I confin'd my ſelf to what is purely practical, (how uſeful ſoever that be) but have introduced what I had to ſay, with all or moſt of thoſe uſeful Propoſitions and Theorems that Writers in theſe Sciences have laid down, that ſo I might, as it were with a Clue of Thread, lead my Reader thro' the delightful Avenues and Approaches, till he is brought to the more ſatisfactory Pleaſures which attend the ſolid Practice of them.

The firſt Thing I have attempted at, is an hiſtorical Account of the chief Works of this Kind, that were and are remarkable in ancient and modern Times, and the Riſes and Honour they have contributed to the reſpective Places where they have been uſed, which has neceſſarily taken in a great many Obſervations of

considerable Uſe in the following Treatiſe; Obſervations ſo juſt in themſelves, and of ſuch great Conſideration in Life, that whoever reads the Hiſtories of thoſe Times, will find, that the watering of a Town, and the preſerving and conducting a Rivulet or a Spring (eſpecially in military Affairs) was of as great Importance as the Conqueſt of an Enemy; and that without this Care, whole Armies have periſh'd: *Cæſar* no Doubt was as remarkable for his Skill in Hydroſtaticks, or rather Hydrophanticks, as he was in any other Effort he made for the Defence of his belov'd *Alexandria*, when he was ſo cloſely beſieged in it; His whole Life, and ſome of the greateſt and moſt politick of all his Actions alſo (as may be ſeen in the *Roman* Hiſtory) being one continued Chain of Care, how he ſhould procure Water for his Friends, and divert it from his Enemies, by which he often relieved his own, and ſtarved the Armies of his Antagoniſts: And *Alexander*, how great ſoever he was in other Reſpects, was as remarkably negligent and ſupine in this, in ſuffering his Army to periſh for Want of it.

Rome, even in its civil Capacity, was (as the Courſe of this Account will demonſtrate) an eminent Inſtance of the Uſes it was of to that Metropolis, in the ſtupendous Aqueducts with which it was on all Occaſions ſupplied, ſuch as cauſed *Fabretti*, a celebrated Author of Antiquity, to write a Treatiſe on Purpoſe concerning them; by which, as well as from *Pliny* and other Writers, we are aſſured they were accounted one of the Wonders of the World: Nor are *France*, *Italy*, as well as many other European Countries, much behind them

them, all which will be more amply confidered in its proper Place.

THAT I might proceed the more methodically, the next Thing I have done, is the fumming up all the different Hypothefes which have been laid down, relating to the Original and Rife of Springs, which I place as the Ground-work of this Undertaking; fince that, as well as other Parts of Philofophy, whofe Caufes lie conceal'd, have long entertain'd the World with different Reafonings: All which I have endeavour'd as much as poffible to reconcile, and to give every Opinion, which has any tolerable Appearance of Truth in it, its due Weight and Emphafis, not taking upon me abfolutely to determine an Hypothefis, in which fo many learned Men in all Ages have differed.

THE Original and Rife of Springs being thus cautioufly, but I hope clearly handled, I have in the next Place treated in as fhort but yet plain a Manner as I could, of the good and bad Properties of Water, the Manner of difcovering and fearching for Springs, the taking of true Levels, in order to the conducting them home, where they are to be ufed in Aqueducts or Pipes of Conduct, according to the Practice of the moft experienc'd in this Way; and this Book has neceffarily taken in the cheapeft and beft Methods of Pipes, the making of Aqueducts, Refervoirs and Bafons; becaufe it is from the Want of this Knowledge that I fufpect many great Defigns of Water are laid afide, as not practicable or confiftent with the Pockets of many Perfons who have Occafion of it, in which I have more particularly explain'd the new invented, at leaft the fo much new improv'd Earth

Pipes,

Pipes, for which the ingenious Mr. *Edwards* of *Monmouth* has a Patent; and which, as we are inform'd, by the Reverend Dr. *Desaguliers*, in the *Evening Post* of *August* 1*st* this present Year 1727, did bear all the Compressure of Air and Water that the *York-buildings* Engine could lay upon it; and that without making the least Fracture, either in the Pipe, or the Cement that join'd the Pipes together, which has brought me to what was my next and indeed principal Aim, I mean, the Theory and Practice of Hydrostaticks and Hydraulicks: From the first of which, we learn the Motion and Equilibrium of Water and other Fluids, from their Gravity, Elasticity and Impulse, and from the latter, a Mechanical Account of those Powers, by which Water is thrown up out of the deepest Wells and Caverns, to the Tops of the highest Hills.

" Hydrostaticks (says the honourable and ingenious " Mr. *Boyle*, in his Preface to his Hydrostatical Para-" doxes) is a Part of Study or Philosophy which ought " to be look'd upon as the most ingenious of any; " the Theorems and Problems of this Art, being " the handsome Productions of Reason, and affor-" ding the noblest Discoveries, not only pleasing, but " also most surprizing and wonderful; in that most " of the Phænomena of Nature can hardly be under-" stood, without Hydrostatical Principles." For the Illustration of which, I have made Use of those Experiments which have been laid down and explain'd by that Honourable Author, with others of great Note amongst the Learned, corroborated by an Experiment, which, in Honour of its Inventor, will in all Probability be called *Torricellian*, as long as Time it self shall last.

To

2

To go on with our learned Author, " This Art is " not only ſpeculative, but practical, the Propoſiti- " ons belonging to it being very uſeful in Navigati- " on, (and that whereby the Burthen of every Ship of " ſuch and ſuch Dimenſions is known) but alſo in all " other Arts and Sciences, where Enquiry is made in- " to the Gravities and Magnitudes of different Bodies; " and it is alſo poſſible, to make the Art of Hydroſta- " cy to be variouſly uſeful to all Profeſſors of Medi- " cine and Chymiſtry, as that learned Author has de- " monſtrated, in a moſt curious Treatiſe of his, enti- " tuled, *Medicina Hydroſtatica, &c.* to which I refer " my Phyſical Reader. " And if the Study of Hydro-ſtaticks is ſo uſeful in the *Materia Medica*, and to all Dealers in Medicine, ſo it is no leſs uſeful to thoſe whoſe Office obliges them to the Practice of the *Medica interna* itſelf; becauſe, according to the excellent *Boerhaave* (in his well wrote Method of ſtudying Phyſick) a Phyſician ought to be well acquainted with all the Laws of Motion, with Staticks, Hydroſtaticks, and Hydraulicks, and the Properties of all Fluids, of which more by and by. To proceed to Vegetation, the Riſing and Aſcent of the Sap and other Liquors in Trees and Capillary Tubes, is not to be accounted for any other Way, than by Hydroſtaticks; and to ſo great a Pitch did ſome of the Ancients carry this Notion, that they ſuppos'd (as *Bockler* has it) that they ſhould taſte of the Joys of Heaven, as thro' a Syphon, of which more hereafter.

Later Philoſophy is indeed much plainer, in the Demonſtrations it gives of this wonderful Part of Nature, it being by Attraction, or in other Words by Pulſion,

Pulſion, (a great Principle in Hydroſtaticks) it is as moſt learnedly hinted at by Sir *Iſaac Newton*, in his *Principia*, that the Sap is made to aſcend the Trunk and Boughs of Trees, and all other Vegetables, which tho' it riſes much higher than by the ſtated Laws of Hydroſtacy, it is ſuppos'd it will, yet it is by the Preſſure or Pulſion of the Atmoſphere, gravitating as it does on this lower Orb of Earth and Water, that Motion it ſelf (with all the Actions of vegetative Vitability) owe their Exiſtence; the Liquids being firſt heated and diſſolv'd by the ſuperior Influence of the Sun in Summer, and of the deſcending Rains which then fall, ſtill cauſing a new Acceſſion and Aſcenſion of Matter, till the Tree reaches up to, and acquires its higheſt Stature. Diſcoveries, which have been chiefly, if not altogether owing to that angelick Genius (if I may ſo call him) who as he excell'd moſt of his Cotemporaries when alive, ſo (may have) now dead, a ſuperior Place in thoſe ſublim'd and happy Regions of Bliſs above, as a Reward for his great Labours.

To proceed, the Laws of Hydroſtaticks are no leſs viſible in the Animal, than they are in the Vegetative Life; it being by the Gravity and Elaſticity of Air, that all thoſe Acts of Motion (on which the Circle of Life depends) are perform'd.

Were it not for the ſuperincumbent Air, gravitating and preſſing upon, and round a Man as he walks, 'tis much to be doubted whether he could ſo much as ſtand upon his Feet; and it is plain, that it is by that Preſſure of the external Air on the Muſcles, that that due and regular Circulation of the Blood which contributes ſo much to Life and Health, has

its

its Motion; for when that Preſſure is taken away, the Skin (as may be ſeen in Cupping) diſtends it ſelf, and makes it ſwell in the Glaſs; the internal Air in the Blood being (as the learned *Deſaguiliers*, *Pa.* 119, of his experimental Philoſophy ſets down) rarified when the Preſſure of the external Air is taken away; and if we look into the Inſide of a human Body, we ſhall there find of what great Uſe this Elaſticity of Air is.

For when a Man (as our oft quoted Author, *Prop.* xviii. *Pa.* 119 on another Occaſion has it) by the Muſcles of his Breaſt enlarges the Cavity of the Thorax, then the external Air (by its elaſtick force) finding Room wherein to expand it ſelf, ruſhes in at his Mouth into the Lungs, and wherever elſe it can find any Vacuity, and cauſes that internal Motion, whereon all the Parts of Life depend; and how miſerable a Thing it is, to be depriv'd of the Elaſticity of that Air ſo ruſhing in, may be ſeen in thoſe Animals, who undergoe the Operation of the Air-pump. This is a Demonſtration of what I have before obſerv'd concerning the Neceſſity every Phyſician and Anatomiſt is under, of ſtudying the Laws of Preſſure, or the elaſtick or impulſive Force of Air on human Bodies.

But to return to what is more principally my Aim in this Treatiſe, as to Experiments in the common Demonſtrations of Hydroſtaticks, I have chiefly made Uſe of thoſe, that the learned *Boyle* and *Wallis* have ſet forth, corroborated and improv'd as they are, by the Obſervations and Experiments of *Marriotte*, *Graveſande*, and others amongſt the Foreigners, with thoſe of their reverend and ingenious Tranſlator Dr. *Deſaguiliers*, by Meſ-

b ſieurs

ſieurs *Watts*, *Hawksbee*, and others of our own Country, who by their ingenious Lectures have been ſo great Improvers of hydroſtatick and mechanick Knowledge. Had even the Riſing of the Water to its firſt Level or in other Words, had it been known, that when any Reſervoir of Water laid 80 or 100 Foot, more or leſs, higher than any ſubjacent Valley, I ſay, that ſuch Water, when confin'd in Pipes, would riſe to very near the ſame Height, on any Hill on the other Side; and ſo on to any diſtant Place, as it was before: The *Romans*, (thoſe great Sages of all Antiquity) needed not to have been at the great Expence they were, in cutting through Hills, or to have rais'd ſuch Arches and Cauſeways as they did, for the Conveyance of Water upon one intire Level, from one Place to another, Undertakings ſo great, that no private Perſon could poſſibly attempt, much leſs finiſh; and which might have been done at a much cheaper Rate, had the Knowledge of Hydroſtaticks been ſo known, as now it is.

THE *Vacuum* of the Ancients was a Poſition that in the Courſe of this Treatiſe I could not help enquiring into; a Point long held in Debate between the Philoſophers of old, from *Democritus*, *Leucippus*, *Anaxagoras*, *Ariſtotle*, and others, to *Macedonus Epicinonus*, *Cleomedes*, and *Hero Alexandrinus*, one of the moſt celebrated Writers in Hydroſtaticks of all Antiquity, as they are ſumm'd up with great Judgment by *Bockler*, ſome denying there was any ſuch Thing, whilſt others as reſolutely maintain'd it; ſome were for placing it in the firſt, others in the middle, but others in the ſublimeſt Regions of the Air: Thoſe who were for it maintaining that Doctrine (wherever the Poſition of it was) ſay that it

it was in that *inane* or empty Space, that were tranſacted all thoſe Momentas, of which Fluidity is compos'd; for that, contrary to the Opinion of the Pleniſts, one Body could not move in another.

On the contrary, the *Pleniſts* deny'd a *Vacuum* from the Impoſſibility there was of it, and that the Aſcent of Liquors in a Syphon or Syringe was from an Abhorrence there was in Nature of any ſuch Thing; and from thence they inferr'd, That Water might be rais'd to the greateſt Height, by Means of a Syphon or Pipe, which, as they had ſeen, in ſmall Experiments of Wine, Water, &c. might be eaſily transferr'd from one Valley to another: And ſo long was this Error continued, that I have ſeen a Book of Machines written, even in Queen *Elizabeth*'s Time, by one *Ward* an Engineer, who ventur'd to give a Sketch of a high Hill, (and a Houſe at the Bottom or Side) over which, by a vaſt extended Syphon, the Water was to be convey'd from one Vale to another.

But in Anſwer to this, *Gallileo*, a very ingenious Author amongſt the *Italians*, was the firſt which found out (as the learned *Wallis, Cap.* xiv. *pro* 14. *Pa.* 743. of his Hydroſtaticks, has it) that this *Fuga vacui,* or this Abhorrence which there was ſuppos'd to be in Nature, of a *Vacuum*, was not infinite, but circumſcrib'd within certain Limitations, and ſubſtituted in the Room of it the *Equipondium*, or *Equilibrium* of Air, preſſing or gravitating upon other Bodies, eſpecially Water, which cauſed the Water, when the Air was ſuck'd out, and the Ballance loſt, to aſcend the Pipe, Pump, or Tube; from which ſome Moderns have divided this *Vacuum* into a *Vacuum diſſeminatum ſeu in-*

terſperſum, and into a *Vacuum coacervatum*, of which more in its proper Place: And to go on, this Thought of *Gallileo*'s was much improv'd by *Torricelli* his Succeſſor, in an Experiment of his, which is already hinted at, and which has put this Matter beyond all Diſpute (I mean the Barometer) where he found by comparing the Weight of Water with Quickſilver, which is Fourteen Times heavier than Water, that Mercury or Quickſilver would not riſe above 28 or 29 Inches, and conſequently Water not above 32 or 33 Foot at moſt; and indeed by what I have obſerv'd, amongſt our Engineers, and Machine or Pump Makers, there are few that will rely upon the natural Aſcent of Water, by the Preſſure of the Atmoſphere, ſo high as that, and therefore generally fix their Suckers, at about 25 or 26 Foot above the Surface of the Water; tho' ſeveral Experiments in Hydroſtaticks inform us, that the lower you go in a Well, the higher the Quickſilver (and conſequently the Water) will riſe; and the higher you aſcend towards the Top of any Hill, with the Barometer in your Hand, the more the Quickſilver will fall. From all which, our modern Philoſophers have inferr'd (and that with great Reaſon) that what the Ancients call'd the *Fuga vacui* (*Gallileo* firſt leading the Way, and who was afterwards follow'd and improv'd by *Torricelli*, *Boyle*, *Wallis*, and a great many others) was no other than the Pulſion or Preſſure of external Air, gravitating on the Surface of Water, which could make it aſcend only to about 32 or 33 Foot high at moſt; tho' the Ancients, by Miſtake, thought that they could make it mount to 200 or 300 Foot, by their imaginary *Fuga*
vacui

vacui (as has been before noted): And this Obſcurity in the Ancients was in a great Meaſure owing to the imperfect Idea they had of the Gravitation of Fluids one upon another, and of the Elaſticity, Dilatation, and Compreſſion of Air, whoſe Effects are now ſo clearly demonſtrated in all modern Calculations and Experiments.

As to the *Firſt*, I mean the Gravitation and Preſſure of Fluids one upon another, and of every Particle of any one Fluid upon that which is under it, that is clearly prov'd, not only by *Archimedes*, in Two excellent Books of his, *De inſidentibus Humido*, in oppoſition to the *Peripateticks*, who would not allow of ſuch a Gravitation, at leaſt *That Water would not gravitate on Water, nor Air on Air*, but alſo by the honourable and ingenious *Boyle*, *Wallis*, and others; and yet more particularly by *Ozanam*, *Marriotte*, *Graveſande*, *&c.* as they are judiciouſly explain'd by their reverend and learned Tranſlator, Dr. *Deſaguiliers*, even beyond all Diſpute; which has alſo been the Occaſion of ſeveral ſelect Tables, to be found in Sir *Jonas More*'s *Compendium*, *Ozanam's Curſus*, the Tranſactions of the Royal Society, and the like Places.

And this Gravitation of Fluids one upon another, according to their reſpective Weights, muſt be own'd to be one of the greateſt Momentas in all Hydroſtatick Knowledge, *The Weight of unknown Bodies being found out, by the Weight and Capacity of thoſe that are known*, as was that of King *Hiero*'s Crown ſo judiciouſly diſcover'd by *Archimedes*, as he was bathing himſelf in Water: Of which more in its proper Place.

The Weight of Air is not the leaſt, in the Diſcoveries that have been made in Hydroſtaticks; for who amongſt

the Ancients could have thought that Air (thin and ſubtile as it is) ſhould ever have been reduc'd to Weight and Meaſure; yet ſo it is, that from undoubted Experiments it is found, that a Cylinderical Column of Air, whoſe Diameter is ſeven Inches, and its Length a Yard, weighs about one Ounce *Averdupois*: Nor will this be judg'd a needleſs Speculation in Hydroſtaticks, when we treat of the Impulſe of Air againſt the Sails of Windmills, *&c.* if to it be added what *Marriotte*, and from him the Reverend and ingenious Dr. *Deſaguiliers* have from Experiments ſet down, that though the Weight of Air is ſo much leſs than that of Water, yet its Velocity is greater: So what was wanted in the Gravity of one, was fully made up in the Elaſticity and Impulſe of the other.

AND as it is chiefly owing to the Induſtry of our modern Philoſophers, that theſe and other wonderful Diſcoveries relating to Air are found out; I mean as to its Gravity, Elaſticity, Rarefaction, Condenſation, and other Diſpoſitions of the ſame Nature juſt now recited; ſo alſo in Water, there are a great many Diſcoveries of the ſame kind; it being to the Labours of the illuſtrious *Boyle*, we owe the Knowledge, that 13,000 Particles of Water may hang upon the Point of a Needle, that one Drop of Water is diviſible into 26 Millions of Parts, and that a Cubick Inch contains 13,300 Millions of ſuch Vapour. Had this been rightly underſtood by the Ancients they need not have laboured ſo long under the miſtaken Notion that Water ſo expanded could find Room enough for ſuch ſudden Tranſmutations, which they imagin'd were perform'd in the Bowels of the Earth for the regular Supply of all Perennial Springs.

BUT

BUT to return to the farther Account of this Elaſticity of Air, from which this laſt Paragraph is a kind of Digreſſion, 'tis there may be ſeen a wonderful Work in Nature, and without which there would ſoon follow a Stagnation, and conſequently an Annihilation of all ſublunary Things; and that contrary to the Opinion of the *Pleniſts* and *Vacuiſts*, thoſe Enemies to Reaſon, it is ſo made as to recede and give Place to all Bodies whatſoever, which are more Weighty and Ponderous than it ſelf, returning afterwards to its firſt Poſition, and maintaining its fluctuating Motion; and that it ſhould at the ſame Time be capable of Dilatation and Compreſſion to ſuch an infinite Degree, is what at firſt Sight ſeems impoſſible; Diſcoveries which have had their Riſe chiefly to the Induſtry of the laſt Century, and to the immortal Honour of the *Royal Society*, and its noble and ingenious Profeſſors: Nor will that excellent Diſcourſe of the Honourable Mr. *Boyle* againſt *Linus*, *Hobbs*, &c. on this Subject, be, tis hop'd, ever forgot, as long as good Literature has any Being in theſe Kingdoms.

WHO amongſt the Ancients (and indeed ſome Moderns) could have thought that Air could be dilated beyond its ordinary Capacity, as 13,769 is to 1; and that it could be compreſs'd as 40 to 1; ſo that the Difference between expanded and contracted Air, is as 550,760 to 1; or by a running Number, as 550,000 at leaſt; let me give it in the learned *Wallis*'s own Words, *Ut Quinquies Centena & quinquaginta Millia, ad unum, &, quanto, per Media olim forte Excogitanda. Removeri adhuc poſſit ab invicem uterque Terminus conjicere non valemus.* Vid. Wallis, De Hydroſ. *Prop.* 13. *Cap.* XIV.

THIS

THIS Dilatation and Compreſſion of Air beyond and within its natural State, points out the great Miſtake of *Ariſtotle* and his Followers, who imagin'd that Springs have their Riſe from Air which is condens'd in the Bowels and large Vaults of the Earth: Air being to Water proportionably, as 800 to 1. The Water then riſing in the River *Seine*, as deſcribed by *Marriotte*, muſt have a Cavern of Air to ſupply it (could there be ſuch a ſudden Tranſmutation of Elements) of 160,000 Cubick Feet to ſupply it a Minute, of 9,800,000,000 Cubick Feet to ſupply it an Hour; and of 220,400,000,000 Cubick Feet to ſupply it 24 Hours, or a Day natural; and 571,620,000,000,000 a whole Year; where any ſuch are to be found, there is no Body which I ever heard of, that knows; for this laſt, being reduced, produces upwards of 3000 Cubical Miles, to ſuch great Abſurdities are thoſe Things carryed, whoſe Demonſtrations are Philoſophical and Speculative, rather than Mechanical.

BUT ſhould we for once admit that there can be ſuch a ſudden Tranſmutation of Air into Water, and which poſſibly might be tranſacted in ſo ſhort a Time as a Minute, (tho' that is an Allowance infinitely wide of Truth) ſuch a Receptacle ought to be 500 Foot cubical; and if they were to be divided into 8, 10, or 12 Parts, their Capacities would be infinitely larger than any one that was ever yet ſeen or met with for that Purpoſe, at leaſt that have fallen in the Compaſs of my Obſervation.

TO proceed, the Gravity, Elaſticity, Compreſſion, and Dilatation of Air and other Fluids, is a Subject, that if traced through all its various Circumſtances, is moſt

moſt wonderful and amazing, from whence and however ſituated, or of what Parts this Elaſticity is compoſed: I ſhall, with the learned *Wallis*, not ſpend much Time in delineating; ſome ſay of it, That it conſiſts of innumerable Quantity of Threads or Fibres, and have compar'd it to a Fleece of Wool, or perhaps more properly to a Lock of curl'd Hair, which you may compreſs in your Hand; yet after that Compreſſion is over, it will, like a Spring, return to its former State again; but others, not pleas'd with this Definition, would rather ſuppoſe, that Air is compos'd of an infinite Number of Corpuſcles, or little round Bodies, which, by the Laws of Motion, joſtle and recede from each other, giving Place to all heavier Bodies whatever, which come in its Way; and after that, return into its Place again.

Wallis ſays, That there is a Kind of Elaſticity, even in Marble, Earthen Ware, and in innumerable other hard Things, which is diſcoverable by their Sound, when ſtruck with a Hammer, or any other Inſtrument; but that in Fact there is no Account of Elaſticity, ſo plain as that of a Steel Sword, which though bent a conſiderable Time, will, eſpecially if it be touch'd with a Loadſtone, unbend it ſelf again: Nor does he forbear to aſcribe a certain Degree of Elaſticity even to Lead it ſelf; but the greateſt Inſtance of Elaſticity (if I may ſo call it) that I have ever obſerv'd, is that of mill'd Lead, which being compreſs'd to a great Degree in its Paſſage, between two Rowls in the Mill, that all the Pores are ſo clos'd, as that one would believe they would never retract again; yet upon its Expoſure to the Sun and Air, thoſe compreſs'd Parts will tear and diſſever from one another, being impatient of

that Impriſonment, and to endeavour to aſſume as much as poſſible its natural State again; to uſe the Words of the learned *Wallis*, in an Obſervation of this Kind: *So great is the Affection, even of inanimate Beings, to return to that Poſition, in which Nature, or rather God Almighty, the great Author and Architect of the Univerſe, firſt plac'd them.*

THE Impulſe of the Air, and other Fluids (of Air eſpecially) is next to be conſider'd, being a Subject of that Uſe in Hydroſtaticks, as well as Hydraulicks, that I have been from the laborious *Marriotte* very particular in it; ſince 'tis on this, that the Celerity of the Wheels, and the cylinderical Weight of Water that they can raiſe or drive, that all Calculations in Engine Work (eſpecially Wind-mills depends,) which may either go too faſt or too ſlow, as the Impulſe of the Air or Wind is: Nor is it of leſs Uſe in Water Engines, where there is but a little Water to drive the Wheel, (as it often happens,) and where the great Waſte and Expence of it (were we to put on more than there is really Occaſion for) would prove of very ill Conſequence. In the Theory of this, we ſhall alſo find ſome very curious Obſervations in Nature, which, when reduc'd to Practice, may be of very gteat Service in ſeveral Parts of mechanick and philoſophick Experiments. And thus have I given a ſhort Account of what is to be expected from the ſecond Book of this Volume, which treats of Hydroſtaticks. I proceed to

THE third Book, which is particularly apply'd to Hydraulicks, a Part of mechanick Knowledge ſo very uſeful, that no Body ſhould be without it, though it muſt be confeſs'd, it is generally not ſo well underſtood

ſtood as it might be, except by ſome few Workmen: Nor were the Ancients, as will appear by the Courſe of this Treatiſe, acquainted with it all, at leaſt not in ſuch a Manner, as that they could thereby raiſe what Water was wanted to any great Heights, or well drain any Mine or Ciſtern that lay ſo deep as now we do: Thoſe deſcrib'd by *Vitruvius*, and others amongſt the *Romans*, being mean and trifling, in Compariſon of thoſe, Engineers now produce.

'Tis to *Archimedes*, *Ariſtotle*, and others amongſt the Ancients, that we owe thoſe Principles of Staticks and Mechanicks, that naturally lead to the Practice of the Subject we are upon, improv'd as it has been by *Wallis*, and ſome other latter Writers; ſo that the practical Part of it has receiv'd moſt conſiderable Additions to it, from *Hero Alexandrinus*, *Bockler*, Sir *Jonas Moore*, Sir *Samuel Moorland*, and other Authors of undoubted Repute in the two laſt Centuries; and may I not add, for the Honour of the preſent Age, and that which is juſt paſt by, we have or lately had our *Sorocolds*, *Saverys*, *Deſaguliers*'s, *Hollands*, with a great many others, of great, as well as inferior Note, who have brought the Practice of Engines into great Uſe: But it muſt be own'd at the ſame Time, that how greatly ſoever Gentlemen and others, that have often Occaſion of theſe Things, are vers'd in the Theory; yet the Practice is ſomewhat difficult, nor is it ſo well known to them, as to judge when they are well or ill us'd, or whether their Undertakings are likely to ſucceed or not.

The Scyphon is the firſt Machine I have endeavour'd to deſcribe and improve, and alſo what Concluſions may be drawn from ſmall Experiments, (as de-

canting of Wine, *&c.)* for the Benefit of thoſe which are arger; and here I have taken in the moſt material Experiments of *Graveſande*, *Marriotte*, *Deſaguiliers*, and others, who have put its Uſes beyond Diſpute.

THE Second Inſtrument I have at large deſcrib'd, is the Limace or Skrew of *Archimedes*, with which, it is ſaid, he drew off the great Inundations of *Egypt*, when the *Nile* tranſgreſs'd its Bounds, and is now indeed little other (though perhaps ſomewhat improved) than what is ſo much magnified in the draining off Fiſh-Ponds, *&c.* where the Current is too dead to carry it off by Nature.

THE *Antlia*, or Pump of *Cetſibus*, ſo much fam'd by the Ancients, (and ſo much better underſtood and improv'd by the Moderns,) is certainly the Mother of all Hydraulick Machines; in the Explanation of which, I have endeavour'd by Drafts and otherwiſe, to demonſtrate its Uſes, and the ſeveral beſt Kinds of which it is compoſed.

I then proceed to compound Engines, (after a ſhort View of the Chain Pump ſo much improved by Mr. *Holland)* and take along with me their ſeveral Kinds, whether in Crank or Chain Work; or which is now more in Uſe, the vibrating Leaver, drove as they are all by Wind or Water, by Overſhot, Underſhot, or Horizontal Wheels; in all which, I muſt own my ſelf much indebted to the ingenious *Bockler* in his *Theatro Machinorum*, as well as to the Improvements made by Meſſ. *Sorocold*, *Alderſea*, *Newſham*, &c. Nor ſhall I ſtop here, but with ſome Pains and Expence procure the Plans Profiles, or Perſpectives of ſome of the beſt

Engines

Engines now in Uſe, with their Deſcriptions and the like, that ſo I may perfect what I intended under this Head.

LASTLY, and to conclude this third Book, I have given a full and ample Account of the Fire Engine, the Invention of my late worthy and ingenious Friend Captain *Savery*; an Invention of that Ingenuity and Uſe, if I may be allow'd to uſe the Words of the laborious *Harris* in his *Lexicon Technicum*, that it may be juſtly accounted one of the greateſt Pieces of Art, that perhaps this or any other Country has yet produc'd; this together with the Improvements made by Mr. *Newſham*, &c. as alſo an Account of Engines for draining Fens, puting out of Fire, driving of Mills, which finiſhes this 3d Book.

THE laſt Book of this Treatiſe, and which is indeed the Sum and Corollary of the former three reduc'd to Practice, is concerning the Quantity of Water that comes in from Springs or Engines, and the Expence thereof, in Fountains, Canals, Caſcades, *&c.* deduc'd not only from the Experiments of *Marriotte*, but from the known Quantity that ſeveral Engines and Springs give, corroborated by Practice and Experience.

BUT as the chief Principles and Experiments of this Part of Hydroſtatick and Hydraulick Knowledge are deduc'd from *Gallileo*, *Torricelli* and others, who have made ſome Eſſays towards it in their invaluable Tracts of the Acceleration of Bodies; and as the whole has been enlarg'd upon and explained by few, except *Marriotte* and his Rev. and Ingenious Tranſlator, I have found my ſelf at ſome Loſs how to reduce it to *Engliſh* Practice, the Difference between the Meaſures of *England* and *France*, being greater than at firſt View they may appear to be; ſo that an *Engliſhman* who goes about to calculate

calculate by the Pint, Gallon, Muid, or any other Meaſure of *France*, compar'd with thoſe of our own Country, would find himſelf greatly at a Loſs to come at the Truth of his Calculation.

I need not enumerate, in this Place, the Methods I have taken to reconcile theſe two Kinds of Meaſures (which are ſo neceſſary to be known) one to another, for the Explanation of the curious Examens of our oft-quoted Authors, on whom every Body relies for the Theory of this uſeful Part of Mechanical Knowledge: Becauſe that will appear more plainly in the Courſe of the enſuing Treatiſe, and would have been too long to inſert here; but the Reader may take it for granted, that I have (with as much Exactneſs as I poſſibly could) regulated and compared them both together; conſtantly retaining nevertheleſs ſo much of the *French* as relates to the Diameter of the Pipes of Conduit, Adjutages, or Holes through which the Water ſpouts; becauſe I ſuppoſed that the endeavouring to alter them, would ſtill make my Calculations from *Marriotte* the more difficult; when I have Occaſion therefore to mention an Adjutage, Pipe, or Bore of an Inch Diameter, I would be underſtood ſtill to mean that of the *French* Meaſure, which is in ſingle Numbers to the *Engliſh*, as 16 is to 15, or when ſuperficially taken, as 256 is to 225, or farther, if ſolidly taken, as 40 96, is to 3375.

THE chief Additions I have made to this Part of my Undertaking is, as has been above hinted at, an Account of the ſeveral Rules in Arithmetick, as alſo Tables of the ſeveral Weights and Meaſures of *England*, as fix'd by Statutes, and Acts of Parliament, and Exciſe, compar'd with the *French*, preceding the Practical Calculation

culation of the coming in, and the Diſtribution and Expence of Water in Villa's, Caſcades, &c. which Tables I have enlarg'd from *Marriotte*, and have alſo given Rules for the Thickneſs of Lead in Pipes of Conduit or otherwiſe, which was not done by *Marriotte*, whoſe Calculations were without doubt for Copper.

THEN in the laſt Place, I have added ſome Tables of the Cylinderical Weight of Water, that muſt of Courſe be on all Engines in the raiſing it to great Heights; which when added to the Friction that muſt neceſſarily ariſe from the great Length and Diſtance of Pipes, together with the progreſſive Addition that is in every determinate Number of Yards, in the raiſing of Water to thoſe great Heights, will make the Load that lies on the Tail of a Mill Wheel, (and which ought to be well underſtood) to be as it were immenſe.

THUS in a Pipe of Conduit of 4 or 4 $\frac{1}{2}$ Inches Diameter, which is often the Size of a Pipe for the raiſing of Water 100 or 120 Foot high, I ſay in ſuch a Caſe, and where the Water runs a great Way, as ſuppoſe 15 or 1600 Yards, the Cylinderical Weight of Water encreaſes to a very great Degree.

IT will be found by thoſe Tables, that in every Yard running of Pipe (being 7 Inches in Diameter) there is 57 *l.* 5 *oz.* $\frac{95}{100}$ Averdupois Weight; or to give it in Fractions for the more exact multiplying of it, there is 917 *oz.* 95481 *pts*, which when multiplied by 1600, the Number of Yards in the ſuppoſed Length, the Anſwer is 91795 *l.* 48100 *parts*, which is being reduced to Hundred Weights of 112 *l.* 817 *l.* Weight, and 91 *l.* which added to the Friction and the progreſſive additional Weight that happens in ſuch great Lengths

and

and Heights, ſuch a Wheel cannot ſuſtain leſs than 1200 *l.* Weight, were it ſuppos'd to be ty'd to the Tail thereof; ſo well worth the while are Calculations of this Kind, for the Diſcovery of what Strength the Wheel and all other Parts of ſuch a Machine ought to be; and alſo the Quantity and Expence of Water neceſſary to drive it, and ſupply the Pipe of Conduit at the ſame Time: Nor have I taken this altogether from Theory, but from Practice and Experience it ſelf, as it is found in ſome of the beſt Engines that have been erected in this Part of *Great Britain* as before noted.

AGREEABLE to this, I have not been ſatisfied in what *Marriotte*, and others have ſaid of the coming in of Water (eſpecially from Engines) and that for the Reaſons abovemention'd; for tho' the coming in of Water from a Spring, where the Diſtance is not great, and where the Water is not to paſs over Hill and Dale, may by its regular and uniform Motion produce the Quantities it is generally eſtimated it will, yet the Interſpace there is between the Stroke of every Piſton, ſuppoſing there are 2 or 3 (for more are not neceſſary) added to the Friction which is in great Lengths, no certain Rule can be laid down, rightly to determine one's Practice.

To this may be added, what an ingenious Gentleman, and curious Obſerver of Works of this Nature has remark'd; (*viz.*) that the Interpoſition there is of Air (notwithſtanding the putting in of Wind-cocks) called as it is by Workmen (the *Wind Boundedneſs* of Pipes,) is more or leſs, according as the Shell of the Pipes of Conduit are larger or more or leſs ſolid or porous; thus Elm Pipe, being porous, gives way for the Air, which is

naturally compreſs'd by the more ſolid and cloſer Contexture of Iron, Lead or Earth, all which makes a conſiderable Alteration in the Quantity of Water which Engines produce.

BESIDES, the ingenious Tranſlator of *Marriotte*, in Conjunction with the Reverend Mr. *Lowthrope* (who was well-knowing in Works of this Kind) ſays, from Experience Pag. 289 of *Marriotte*'s Hydroſtaticks; that altho' through a Hole of 1 Inch $\frac{5}{8}$ which according to our *French* Author ought to give nine Tun of Water in an Hour; yet at the Diſtance of 1400 Yards through a Pipe of that Bore which went all the Way, it did not give above five Tun in an Hour; and what was ſurprizing in Experiments of that Nature, was, that the Quantity of Water diminiſh'd rather in Proportion to the Length it did run, than to the Friction on the Sides of the Pipes; for if a ſeven Inch Pipe (ſay thoſe induſtrious Experimenters) and a three Inch Pipe run the ſame Length, as for Example a Mile; the Deficiency will not be on Account of the Friction, but nearly in Proportion to the Quantity of Water that each Pipe ought to give, which is alſo confirm'd by all the Calculations I have been able to make from theſe and other Experiments, and is a Confirmation of what the ingenious Gentleman I have juſt now nam'd has obſerv'd on this Head.

BY the ſame Rules alſo that we calculate the coming in of Water, we calculate the going out or Expence of it, in Caſcades and Fountains, with this Difference; that where the Water goes down a Caſcade, or ſpouts out through an Adjutage or Pipe of Conduct, where

the Fall is regular, and the Height of the Reſervoir and Pipe of Conduct proportionable; there the Water is more certain in its Expence than it can be in its coming in, under the Circumſtances beforemention'd, except it be from a Spring or Reſervoir which lies near at hand, and where the Motion is uniform, conſtant and regular.

THE laſt thing, and which is indeed the Corollary or Reſult of all the reſt, is ſome Deſigns of Grotto's, Canals, Caſcades, Baſins, *&c.* in which Water is ſhew'd to the beſt Advantage, and in a more natural eaſy Manner than is uſually practis'd; becauſe it is for want of this cheap and eaſy Way, that I judge many great Deſigns have not had Water brought to them, nor explain'd as it ought, I mean to that Expence that too often is in fine Grotts, Caves and Caſcades.

I remember ſome few Years ago to have ſeen in *Holland* a very fine one of the firſt Kind, which tho' not above 12 or 14 Foot wide coſt eleven hundred Pounds, ſet as it was with coſtly Shells and other glittering Works, which made it appear like a tinſell'd hobby Horſe, rather than a Work of Nature; and there are now in *England* ſome Works of this Kind, tho' ſomething rougher, that came to four or five hundred; tho' I am perſuaded that as 'tis a known Maxim, *That the nearer we approach Nature the better it is*; ſo a rude grotteſque Piece of Work of this Kind may be done for leſs than a Hundred, ſince tis not in the Beauty of the Materials, but the Proportion of the Work, that this and moſt other Works in Architecture conſiſt.

THE ſame thing I have obſerv'd in Caſcade Works, which are generally made ſo ſmooth and fine that the Water

Water is not broke to Pieces in its Fall, and consequently the Beauty of it is greatly lost, tho' at the same Time the Expence has been immensely great, as is visible in one or two noted Places of this Kind; but this I have endeavour'd to remedy by some more rural and grotesque Designs.

AND thus have I given as succinct an Account as I can, of the Purport of the ensuing Treatise, in the Course of which I have all along paid all the just Acknowledgments which are due to the Labours and Writings of those, both among the Ancients and Moderns, who have gone before me, even from *Aristotle* and *Archimedes*, *Democritus*, *Leucippus*, *Anaxagoras* and others amongst the Ancients, to *Macedonus*, *Epicinonus*, *Cleomedes*, *Vitruvius*, *Hero Alexandrinus* and others of their Successors. As also to *Gallileo*, *Torricelli*, *Boyle*, *Wallis* &c. amongst those which are of a more modern Date. To give a short Account of them,

Aristotle was a well know Philosopher, Master of *Alexander* and the *Peripateticks*, who as he wrote of almost every thing, 'tis no Wonder he should be mistaken in some, as he certainly was in the Original and Rise of Springs, the Gravitation of Fluids *&c.* He wrote several Books in Mechanicks, and was undoubtedly a great Proficient in the Principles of that Science.

Archimedes was a greater and more solid Mathematician than any which wrote amongst the Ancients (not excepting *Euclid* himself) he was an Inhabitant of the ancient *Syracuse*, and was as some say knock'd on the Head whilst he was busively employing himself in drawing Lines for its Defence there are two Books of his now extant which relate to Hydrostaticks, and

which are publish'd by Bishop *Barrow* (amongst many other of his Works) entituled *de Insidentibus Humido*, to which I have had recourse in this Treatise.

HE was the first that discover'd the specifick Gravities of different Bodies, which, as the Story says, came into his Head when he was in the Bath; because having observ'd that his Body rais'd the Water in Proportion to the Room it took up, he guess'd that by that Means he might easily find out whether there was any Silver mixt in King *Aiero*'s Crown, by finding by the different Weights of each, how much more Gold press'd upon the Water more than silver did.

Democritus, *Leucippus*, *Anaxagoras*, and others before nam'd were all of them Studiers of Hydrostaticks, but wrote differently one against another, and maintain'd with great Vehemence the Disputes which long subsisted amongst them, concerning the *Vacuum* and *Plenum*; whose Opinions are all judiciously sum'd up by *Bockler* in one of his Treatises of Hydrostaticks, which is now easily to be had in any of the Booksellers Shops.

Vitruvius is an Author too well known for me to enlarge on his Character, but who (amongst others of his elaborate and ingenious Writings) has distinguish'd himself well in Hydrostaticks or Water-works, especially the Method practis'd amongst the *Romans* in the Conveyance of their Water from one Place to another, and of the Engines at that Time in use.

Hero Alexandrinus is the next I shall mention on Account of his great Skill in Hydrostaticks, and whose Writings are all or most of them now in print, and abridg'd by *Bockler* and others; by all which it appears

that this elaborate Author had not found out the real Aſcent of Water in Tubes or Pipes of Conduct, but that he labour'd under, and was as it were cruciated between the ſo much contended Diſputes of the Vacuiſts and Pleniſts.

Gallileo and *Torricelli* were of later Date, being Architects to one of the Great Dukes of *Tuſcany* ſucceſſively one after another in the 15th Century. *Gallileo* was the firſt that deſtroy'd the Notion of a *Vacuum*, and that found out that the Aſcent of Liquids in Tubes was from an Equipondium of Air preſſing thereon, and not from the *Fuga Vacui* ſo much talked of, and this was much improv'd by his Succeſſor in the Barometer which is always like to carry his Name.

THE learned *Boyle*, *Wallis* and others, were (as they had great Reaſon) tight Sticklers for this Opinion, as was *Morinus*, *Ghetaldus*, *Stevinus* and others mention'd by Mr. *Boyle*, and alſo againſt that Opinion of the *Peripateticks* which maintain'd *Quod Aquam non gravitare in aquâ ; nec aerem in aere.*

THIS the learned *Boyle* has, in Conjunction with *Wallis*, ſufficiently refuted, and alſo have from the firſt Principles of *Archimedes* ſufficiently explain'd theſe great Principles in hydroſtatick Knowledge. The firſt of theſe learned Authors was (as he himſelf hints at) attack'd by a bold north *Britain* whom he does not name; but I take to be one *Sinclair*, who has alſo wrote a Treatiſe on Hydroſtaticks, which is now to be had in ſome Bookſellers Shops, but this was but a ſhort Diſpute in Compariſon of that which he maintain'd againſt *Hobbs* and *Linus* concerning Air, which is alſo bound

up

up in his Works. This noble Perſon was too great a Man for me to attempt to draw his Character.

Wallis was a Cotemporary of his, and was by much a too hard headed Man for any of his Antagoniſts, as Hiſtory and many other of his Works do evince.

Marriotte, *Graveſande*, *Plot Hooke*, &c. are all of them Followers of the eminent Authors I have juſt now nam'd, tho' the two firſt has with the Aſſiſtance of their Tranſlator much improv'd upon the other Authors; nor muſt Dr. *Keil* the ingenious Profeſſor of Aſtronomy in the Univerſity of *Oxford* be forgot on this Occaſion.

Having thus paid a ſhort Tribute to the Memory of thoſe great Men who are dead, at leaſt abſent from us, I come to make my juſt Acknowledgments to thoſe of the Nobility, Gentry, Clergy, and Artificers now alive, who have been aſſiſting to me in this Work. And here I muſt acknowledge the Favours receiv'd from the Reverend and ingenious Mr. *Samuel Lindſey* Chaplain to the late Lord and Lady *Brooke*, who pointed out to me all or moſt of thoſe Books from which I have extracted this Work. To the Works of the Rev. Dr. *Deſaguiliers* it is I in a great Meaſure owe all that is valuable in it, nor can I paſs by in Silence the good Will expreſs'd to me by the ingenious Mr. *Mills* chief Surveyor of the new River Company, whom I have Occaſion to mention anonymouſly in ſeveral Parts of the following Treatiſe.

One of the laſt things I have to do in this Preface is to beg the favourable and candid Conſtruction of all thoſe Noblemen and Gentlemen who have encourag'd thisUndrtaking, and are plea'd to give themſelves the Trouble of reading it. The Errors are not I hope

large nor many, but in the Hurry in which my other Bufinefs is, 'twas impoffible to avoid fome (tho' 'tis hop'd few) of thofe Erratas, which are incident even to thofe who have much more Leifure than I have; fuch as erroneous Concords, Mifpointings, and the like. For it has fo happened, that the Proofs having been fent to me in the feveral Countries where I have been in my Employ, I had neither the original Copy, nor fo much Leifure as I could have wifh'd for to correct the Errors of the Prefs; but was forced to depend on Strength of Memory; and this may have occafion'd fome little Errors in the Quotations I have made from ancient Authors, all which, (if any,) all good natur'd Readers will, I hope, correct.

Another Difficulty I labour'd under (during the writing of this Treatife) was, that being in the Country I wanted the Affiftance of many original Authors, from which I might have drawn (with more Eafe and Certainty) what I have in this Treatife fet down, than I could, not having them in my Poffeffion; the greateft Help that I had being out of the Library (tho' as yet unfinifhed) of my very worthy learned and noble Friend and Mafter, the right honourable the Earl of *Orrery*, at his Seat at *Marfton* in *Somerfetfhire*: But that noble Lord's Collection in that Place being far fhort of what he intends, I could not be fully fupply'd there. The being fo far diftant from *London* was then a great Bar to me likewife, from converfing with fuch ingenious and learned Men as might have help'd me on perfonally, in this laborious and ufeful Work.

Lastly I beg Leave to add a Word or two of the Reafons why I have chofe to call the following

Treatife

Treatiſe an Introduction to, rather than a general or compleat Syſtem of Hydroſtaticks and Hydraulicks; which is in ſhort from the Largeneſs and Extent of the Subject, and from the Diffidence I was under of going well through ſo great an Undertaking; the chief of my Aim being to reduce the moſt material Parts of theſe Sciences into one Volume, which may, 'tis hop'd, induce ſome more able Pen to give a finiſhing Stroke to a Work ſo diverting in itſelf and ſo beneficial to Mankind.

TILL that is done, the good natur'd Part of the World will ('tis humbly hop'd) excuſe my Preſumption in aiming at ſo great a Work as this is, the Paths of which ſo few have trod before me (eſpecially in the comprehenſive Manner in which this is endeavour'd to be drawn); this added to the Diverſion I have had in compiling it, and in taking (tho' but a tranſient View,) of ſome of the moſt wonderful Phænomena's of Nature, will ſufficiently recompence the Pains I have been at, and ſet me above the little Cavils of mercenary and pretended Wits.

THE

CONTENTS.

VOL. I. BOOK I.

Chap.

1. *Concerning the Water-works of the Ancient* Romans, French, *&c*, Page 1
2. *Of the Origin and Rise of Springs, and of the Opinion of those who ascribe them to Air, Vapours, Dews, Rain, Snow,* &c. 14
3. *Of the Opinion of those, who with more Probability, attribute the Original and Rise of Perennial Springs to subterraneous Causes,* &c. 32
4. *Of irregular Springs, and the Method by which they are transmitted to the Surface of the Earth, and lose their saline Properties* 63
5. *Of the Method of discovering and searching for Springs; their specifick Qualifications, and the like* 76
6. *Of the Instruments proper for, and Method of taking the Levels or Falls of Water from a Spring-head, to a Mansion-house, Building, Reservoir, Garden, Pond,* &c. *and the Allowances to be made in Levelling, for the Curvature of the Earth, Descent of the Water, and the like* 84
7. *Of the proper Methods to be taken in the adjusting the Levels or Falls from a Spring-head, so as to conduct them by a gradual Descent to the House, or other Place required* 102
8. *Of the conducting of Water by Aqueducts, Drains,* &c. 110
9. *Of the several Kinds of Pipes for the Conveyance of Water, whether Lead, Iron, Earth, or Wood* 115

The CONTENTS.

Chap.

10. *Of Reservoirs, Basins, &c. the Method of making them, their Construction, proper Extent, Depths, and other Dimensions* Page 127

BOOK II.

11. *OF Hydrostaticks, its Etymology, Definitions, &c.* 129
12. *Of the Gravitation of Fluids, according to the Honourable Mr.* Boyle 140
13. *Of the so much disputed Vacuum of the Ancients, and of the natural Effects of Air, and other Fluids in Hydrostaticks* 165
14. *Of Air and its Effects in Hydrostaticks, by its Gravity, &c.* 184
15. *Of several Instruments whereby the Principles of Hydrostaticks are more fully explain'd* 196
16. *Of Air, and its Effects in Hydrostaticks, by its Elasticity: As also, of its Dilatation and Compression* 220

13.* *Of the Impulsive Force of Air, and other Fluids in Hydrostaticks* 252

14.* *Of the different Impulse or Fluctuation of Water in a Mill-Pond or River, for the driving of Mill-Wheels, varied according to the different Circumstances which attend the Fall of it* 261

15.* *Of Mill-Wheels for raising Water, &c. their Dimensions, Strength, Position, and the like; and also the best Places for setting of Mills* 272

N. B. By Mistake of the Printer, 14, 15, 16, with this * Mark, were printed in the Place of 17, 18, 19.

VOL. II. BOOK III.

20. *OF Hydraulicks, its Etymology, &c.* 275
21. *Of the Mechanick Sciences, and their Uses in Hydraulicks* 279
22. *Of the Siphon, and other artificial Fountains and Jets of Water* 294
23. *Of the Antlia or Pump; its Description, Uses and Kinds, &c.* 298
24. *Of the Chain-Pump* 313

The CONTENTS.

Chap. Page

25. *Of Crank-Work, and of regulating Engines* 316
26. *Of the Crank-Work, vibrating Leaver, and complicated or Treble-Wheel Engine for raising Water* 318
27. *Of the vibrating Leaver and Crank-Work Engine, with a single Wheel only, to give them Motion* 321
28. *Of the Engine for raising Water by Fire* 325
29. *A Description of the Engine to raise Water by Fire, fixed in a Frame of Timber, instead of the usual Engine House, as improved by Mr.* Newcomen 336
30. *Of several Machines for the playing of Musick* 343

BOOK IV.

30. *A General Introduction concerning the coming in of Water from Engines or Springs, and the Expence thereof in Cascades and Fountains* 353
31. *A farther Calculation of the coming in of Water from Engines, or otherwise* 359
32. *Of Friction, its Etymology, and the Effect it has on Pipes of Conduct*, &c. 365
33. *Of the several Rules in Arithmetick, of which a Learner in Hydrostaticks ought to be informed* 373
34. *Of several Weights and Measures necessary to be known, for the better explaining the Division, Distribution and Expence of Water* 379
35. *Of Artificial Fountains*, Jets d'Eau, &c. 391
36. *Of the Construction and use of a Gauge for measuring of Water, and of the Distribution and Expence of it to Cities, Towns, Gardens*, &c. 398
37 *A Description of the Thirty last Plates* 402

ERRATA.

PReface *Page* 1. *Line* 5. *for* never *read* neither. *p.* 10. and *p.* 26. *for* Epicinonus *read* Epicinous. *p.* 20. *l.* 13. *for* Cetſibus *read* Cteſibius. *p.* 21. *l.* 11. *for* Newſham *read* Newcomen. Ch. p. 1. *p.* 2. *l.* 39. *for* Ittan *read* Ittau, *p.* 13. *l.* 38. *for* Durham *read* Denham. *p* 22. *l.* 3. *for* Nieuentyl *read* Nieuwentyt. *p* 23. *l.* 15. *for* 2380500 *read* 238050. *p* 25. *l.* 1, *&c for* Deerham *read* Derham. *p.* 28. *l.* 29. *for* higher *read* lower. *p.* 29. *l.* 18. *read* don't contribute much. *p.* 37, 49, 66, 76, 82, 103. *for* Varennius *read* Varenius. *p.* 119. *l.* 17. *for* Thyrle Ernby *read* Kyrle Ernly. Notes Book II. *p.* 4. Col. 1. *l.* 19. *for* A B *read* A H. Fig. 4 Tab. 6 *Ibid. l.* 21. *for* D. E. *read* G. I. *p.* 214. *l.* 34. *read*, It has been objected by the Enemies of the Barometer, that the ſlow Aſcent of the Mercury adds nothing to the poſitive Diſcovery of the future Serenity of the Weather. *p* 257. *for* Fig. 3. Tab. ſeq. *read* Fig. IX. *Ibid. for* Fig. 8. *read* Fig. X. *p.* 263. *l.* 32. *for* E F *read* H F. and *l.* 42. *for* Fig. 11. *read* Fig. 10. *p.* 269 *l.* 6. *for* Fig. 5. *read* Fig. 13. and *l.* 24. *for* Fig. 6. *read* Fig. 14 *p.* 270. *l.* 2. *for* Fig. 5. *read* Fig. 13. *p.* 271. *l.* 2 *for* Fig. 5. Tab. ſequentia *read* Fig. 13. Tab. preced. *p.* 355. *l.* 38. *read* Plate V. *p.* 368. *p.* 357. *for* Fig. 1. Tab. ſeq. *read* Fig. 3. *p.* 368. *p.* 362. *l.* 12 *for* 8 Diameter *read* 12 Diameter. *p.* 363. *l.* 3. *read* 12 *for* 8 Diameter. *p.* 367. *l.* 14. *for* Fig. 1. Tab. ſeq. *read* Fig. 1. N. 2. Tab. ſeq. In the Notes, *p.* 108. *for* it will paſs freely; *read* it will not paſs freely.

DIRECTIONS to the Bookbinder.

I. Place the Title of the ſecond Volume before BOOK III. *Page* 275.

II. Place the Cuts marked *Page* 352 at *P.* 350.

III. Place the Contents after the Preface to the firſt Volume.

IV. Place the 30 laſt Cuts at the End of the 4th Book, before the Notes.

V. Place the Notes of the 2d Book after Page 274: which ends the firſt Volume.

AN

INTRODUCTION

TO A

General SYSTEM

OF

HYDROSTATICKS and HYDRAULICKS.

BOOK I.

CHAP. I.

Concerning the Water-Works of the Antient Romans, French, *&c.*

IT would be needleſs for me, in this Place, to entertain my Reader with any long Account of the great Uſe and Beauty that Water (whether brought by Engines or otherwiſe) contributes to a Country Seat, as well as Cities and Towns; Examples of which every Day's Experience, as well as the Accounts received from Abroad, do ſufficiently evince.

That, as to the Uſes of it, it is undeniably the Axis on which Nature turns, it being from the two Principles of Heat and Moiſture, that all Action is given both to Vegetables and Animals, animated by the Heat of the Sun, and a Kind of Spirit, or Salt, which is latent and undiſcovered in the Bowels of the Earth, and in the Blood of all Animals, Fiſh, Fowl, *&c.*

On Plants, in particular, it is evident that this Spirit, or Salt, (call it which you will,) can have no Effect, unleſs it be diſolved by Water, being, as it were, fettered to the Earth, and uncapable of doing any Thing neceſſary to any new Productions, but when diſolved by Water, and mingled with the Parts of the Earth; and thus animated, communicates itſelf to the Roots to nouriſh them; and, by a due Conjunction of Heat, digeſts that Nouriſhment, and turns into the Subſtance of Plants themſelves.

That, as to the Animal Syſtem, it is the All-in-all by which Life itſelf (next to the Spiramina we every Day and every Moment breath) is preſerved, being the Vehicle by which all Nouriſhment is carried to the reſpective Offices of the Body, and without which there would ſoon be an Annihilation and Stoppage of them; and, ſure it is, there is nothing, neither in the Vegetable nor Animal Kingdom, that is or can be tranſacted without it.

Homer ſeems to have this in View in that charming, as well as uſeful Deſcription he gives of the celebrated Gardens of *Alcinous*; where, after he had water'd the Plantations of his renowned Hero, and embelliſhed them with Fountains, Caſcades, *&c.* he diſtributes the Remainder to his Subjects in the lower Part of the Town by ſubterraneous Aqueducts and Pipes, as tranſlated by one of our moſt excellent Bards.

Two plenteous Fountains the whole Proſpect crown'd,
This through the Garden leads its Streams around,
Viſits each Plant, and waters all the Ground:
Whilſt that in Pipes beneath the Palace flows,
And thence a Current on the Town beſtows:
To various Uſe the various Streams they bring;
The People one, and one ſupplies the King. Hom. Odiſ. 7.

Some of the next Works of the Ancients of this Kind, that we have an Account of, were thoſe of *Solomon*, who, as *Joſephus*, in his *Jewiſh Antiquities*, *Cap.* viii. *p.* 204. tells us, had delightful Water-Works, and enriched Gardens at *Ittan*, about ſome eight Leagues Diſtance from *Jeruſalem*, whether he uſually and willingly retired

retired himſelf for his Pleaſure, uſing all Things with admirable Providence and Promptitude, agreeable to the Account which he himſelf gives, of his beautiful Vineyards, Gardens, Orchards, and Pools of Water, mentioned in that admirable Treatiſe of *Eccleſiaſtes*, or the *Preacher*, *Chap.* viii. 4 & 5.

The remarkable Ciſterns at *Roſelayn*, ſome few Miles diſtant from the antient City of *Tyre*, were, by common Tradition, ſuppos'd to be the Works of that Royal and Moſt-wiſe Prince, as a Part of Recompence to *Hiram*, for thoſe Supplies of Materials ſent by him towards building the Temple, tho' others aſcribe it to a much later Date, and that they could not be built till ſince *Alexander*'s Time, being carried over an *Ihſtmus*, or Neck of Land, that was raiſed by that Puiſſant Monarch during the Time he beſieged that City, whereby he join'd it to the Continent.

However it be, there are (as Mr. *Maundrell*, in his *Journey from Aleppo to Jeruſalem*, gives an Account) at this Day three Ciſterns, or Reſervoirs, which not only drive the four Mills that ſtand between that Fountain and the Sea, but alſo ſupply that ancient and celebrated City with Water, for all Kinds of Uſes : One large Ciſtern of twenty-two Yards Diameter, made of no other Materials than Gravel and ſmall Pebles, but conſolidated with a ſtrong tenacious Cement, ſo that it appears to be one entire Veſſel of Rock, elevated nine or ten Yards above the Ground ; which could be no ſmall Expence, but a Demonſtration that thoſe primitive Genius's eſteemed Works of this Kind worthy of their greateſt Labour, Care, Attention, and Expence.

One of the other Ciſterns was of twenty Yards Diameter, and the other of twelve Yards; which being joined together, have for a long Tract of Time ſupplied one of the antienteſt, as well as largeſt Cities of the World with Water.

The next Water-Works we have an Account of, were thoſe ſtupendiouſly admirable ones of *Semiramis*, who, when ſhe built or enlarged the Walls of *Babylon*, turned the River *Euphrates*, as ſome ſay, into a Baſin of forty Miles Square, whilſt ſhe perfected that great Work, and till ſuch Time as a new Canal was formed for the Reception of the River, with the ſeveral Trenches through which it was convey'd. What could be the Reaſon why ſuch a Baſin, as is before mentioned, ſhould be made, is not eaſy to conceive, ſince the new Canal might have been dug, during the Continuance of the old one, (as we now do our new Rivers, during the Continuance of thoſe that were running before;) and beſides, even forty Miles Square could not long contain ſo great a River as that

which the *Euphrates* was, (were it poſſible ſuch a Baſin could be dug:) And, indeed, the whole would ſeem fabulous did not ſo many great and learned Men affirm it; and that a very ingenious Author, on a Survey of thoſe numerous Armies and Subjects that were always at her Command, and to ſhew the Prowefs of ſo great a Princeſs, ſeems to aſſent to it, I mean the ingenious Author of the Spectators. Vol. VI. No. 415.

The ſtupendious Aqueducts, and other Contrivances for Water in *Rome*, and other Parts of *Italy* and *France*, who copied after them, are eminent Inſtances, that thoſe great and wiſe People placed them amongſt their greateſt Improvements of Architecture, (whether Civil or Military,) as they were indeed more uſeful, and contributed more to the Safety and Neceſſity of their publick Communities than any of their other Works could; and their Aqueducts and Cloacas were ſuch, (being raiſed on prodigious high Arches,) that *Pliny* took occaſion to ſay, That the City of *Rome* was ſuſpended in the Air.

Montfaucon, in his *Antiquities of Rome*, Vol. IV. *Page* 165. ſays of them, " That they were one of the Wonders of the World; " and that there were many of them which brought Water thirty or forty, and ſome ſixty Miles Diſtance from that City: That there " are conſiderable Remains of them in the Neighbourhood of *Rome* " to this Day, being long Rows of Arches, over which the Water was " carried, (as it is now between *Marli* and *Verſailles*,) for many " Miles together: Thoſe Arches (ſays he) are ſometimes high, " and ſometimes low, as the Inequality of the Ground required: " That they were built of Brick well cemented together: And " that in all Places where the Ground was too high and Rocky, " they bored through them, that the Courſe of the Water might " not be interrupted. And what was very remarkable, thoſe " Aqueducts which might have been carried ſtrait, were made turning and winding, not unlike the *Ziczac's* now in uſe in Gardens; " which (according to the celebrated *Fabretti*, with whom later " Experience alſo agrees) was for the taking Advantage of high " Ground; for had they been carried through Ground that was " lower, the Arches muſt have been of a much greater Height " than they were, and conſequently the Expence would have been " (tho' not much perhaps conſulted by thoſe generous and great " People) much larger."

That the Stoppage of the Water, which was occaſioned thereby, was for its Purification, or that the Impetuoſity of it was thereby reſtrained, (according to *Flaminius Vacca*,) is a Suppoſition that ſeems

ſeems not to carry with it the Weight which *Montfaucon* ſuppoſes, ſince the more Obſtructions Water meets with, the more turbid and leſs pure it is.

The aforementioned Author *Fabretti*, who appears to reaſon very much like an Architect, and whoſe Drawings Monſ. *Montfaucon* has exhibited, gives both the Images, Sections, and Account of the *Aqua Maria*, *Claudia*, *Julia*, *Tepula*, *Marcia*, and *Neroinana*, which was brought in ſeveral Canals: That which conducted the *Aqua Claudia* was built of ſquare Stone, and that of *Neroinana* of Brick, and, according to *Fabretti*, was ſeventy two *Roman* Foot high: The Canal of the *Aqua Appia* was not made like other Canals, but was diſpoſed within into Steps as it were, ſo that it grew narrower and narrower towards the Bottom.

What would be remarkably prodigious, would be the great Height of thoſe Aqueducts, if we were not at the ſame Time told, that there were three or four ſeveral Canals, through which thoſe ſeveral Sorts of Water was convey'd from different Springs of different Heights, and for different Uſes, and which thoſe great Architects reduced into one Pile of Work, not only as it was commodious for their then Undertakings, but to exemplify the Greatneſs of that State, which did not (as may be ſeen in almoſt all their publick Works) conſult Expence ſo much as Grandeur, ſince, as *Montfaucon* obſerves, it is ſo aſtoniſhing that few (it may be added, except the late King *Lewis* XIV. of *France*) would have undertaken ſo ſtupenduous a Piece of Work from that, even to this Day.

To proceed, (with that laborious Author,) the admired Aqueduct of *Metz* was a Work worthy of the *Roman* Grandeur and Magnificence, being built over the *Moſelle*, a great River; and at that Place very broad, where thoſe Waters were gathered into a Conſervatory, and from thence conveyed thro' ſeveral Canals, made of ſquare Stone, and ſo ſpacious, that a Man might almoſt walk upright within them. Another of the Aqueducts our celebrated Author makes mention of, is that of *Segovia* in *Spain*, which he tells us may be reckoned amongſt the moſt excellent Monuments that Antiquity has tranſmitted to us; and that there remains at this Day an hundred and fifty nine Arches, all built with large ſquare Stone, without any Cement; and that they were one above another in two Rows, the Heights of which, taking in the whole Structure, is an hundred and two Foot; and that the Aqueduct is carried thro' the City to the higheſt Ground.

Even

EVEN the Cloaca, or common Sewers of *Rome* before mentioned, the Work (as the Reverend Mr. *Echard*, in his *Roman* Hiſtory, tells us) of the firſt and great *Tarquin* himſelf, were alſo celebrated amongſt the Wonders of that Miſtreſs of the World; and ſo large, that People might row through them with Boats, (as ſome few Years ſince we have heard of thoſe of *Cremona*;) and the Breadth and Height of ſome of them was great enough, for a Waggon loaded with Hay to paſs through them; and for the cleanſing of which, there was ſuch an incredible Quantity of Water brought to *Rome*, that it was impoſſible any Stoppage or Stench ſhould well happen.

TO conclude this Account of *Rome*, the *Claudian* Aqueduct, (as Mr. *Addiſon* obſerves, VOL. II. Page 131. of his Works,) was thirty eight Miles in Length, through which the Water was brought to *Rome*, by the Advantage only of a high Source, and the low Situation of that City, and that the Architect has allowed five Foot in a Mile, for the Deſcent or Current of the Water that paſſes through it; which I mention, becauſe it is an Obſervation that *Montfaucon*, nor no other Author of the Accounts of *Rome*, (that I have ſeen,) take notice of, and may be a Demonſtration of the curious Enquiry of that deſervedly ingenious Gentleman, who by his Works has been ſo great an Honour to his Country, and one amongſt the many Arguments that might be produc'd, that his Writings can never be juſtly too much admired.

To enumerate, and put down at large, all the Works of this kind, which have heretofore been done in *France*, or thoſe lately done in *Muſcovy*, would be a juſt Volume itſelf. That noble Canal, which according to ſome Hiſtories I have ſeen of *France*, was done, (as I remember,) by *Henry* IV. ſomewhere about *Tholoun*, is a Work worthy of the Magnificence of one of the greateſt Potentates on Earth.

THE Account of the Water-Works of *Verſailles*, would, (with the Machine of *Marli*, the Length and Difficulty of the Paſſage of the Water from thence to *Verſailles*, the Reſervoirs, Canals, *&c.*) be a perfect Hiſtory itſelf, having without doubt coſt ſuch immenſe Sums of Money, as few Princes in the World would again lay out, and therefore beyond the Example and Imitation of inferior Subjects, for whom this Work is chiefly calculated; and I have been very credibly inform'd, that a Nobleman of the firſt Rank of this Kingdom in particular, (I mean that great Duke of *Bolton*, the Grandfather of his preſent Grace, the remarkable *Brutus* of his Age, that like that firſt *Roman* Noble, feign'd himſelf mad, (as his Patent ſets forth,) to

ſave

ſave his Country,) ſold as much Lead towards the Fountains and Baſins, as brought him in at leaſt 250000 *l.* Sterling, clear of all Expences.

THOSE Pieces of Water (as they are by the *French*, by Way of Irony term'd) are by the Prints, as well as by the Accounts Travellers bring, all noble and large, (though the Water itſelf be not very clear;) and the Numbers of them are ſuch, that there is not, in the Compaſs I propoſe to myſelf in this ſhort Hiſtory, Room to ſet them down.

To omit then the Fountains or Baſins of *Saturn*, *Flora*, *Bacchus*, *Ceres*, and *Latona*, with the Pyramid in the Parterre on the North-Corner of the Caſtle, and many others of leſs Account, there are five or ſix Pieces that claim the Attention of the moſt Curious.

AND the firſt is the grand Obeliſque or Mountain of Water, which has one very great Gerb compos'd of two hundred and thirty one Jets of Water, and which riſes fifty Foot high. The Obeliſque, which is at leaſt four or five Foot Diameter at the Bottom, and about one or two at Top, may be juſtly accounted one of the greateſt Pieces of Art and Expence (when we conſider that innumerable Quantity of ſmaller Pipes that join to compoſe it) which is to be ſeen in that or any other Country.

The Baſin of *Apollo* is alſo ſixty Toiſes long, and forty five wide. The Groupe of *Apollo*, with the Tritons, Sea-Horſes, and other Genii, with that grand Gerb which riſes ſeventy Toiſes high in the Center of the Baſin, and fronting the Middle of the great Canal, the Deſign of the famous *Le Brun*, may be juſtly accounted amongſt the greateſt Works of that magnificent Place.

THE Baſin of *Neptune*, another Deſign of that great Maſter's, is a moſt beautiful Piece of Water, adorn'd as it is with above fifty large Jets, that play twenty or thirty Yards high each, and adorn'd with ſeveral Napes, and twenty two Veſſels of fine Metal. This Baſin, according to the *French* Meaſure, is one hundred Toiſes long, and ſixty wide; and being ſituate at the lower End of the fine Alley of Water that comes through the Wood-Work, from the North-Corner of the Caſtle, makes (as appears by all Accounts) one of the nobleſt Figures of any of the Water-Works about the Gardens.

I SHALL but juſt mention the grand Theatre, and triumphant Arch of Water, the Deſigns of Mr. *Le Nautre* and *Le Brun*, adorn'd by almoſt an innumerable Company of leſſer Fountains, Caſcades, Jets, Buffets, Groupes, and other Embelliſhments; which when they are in order, and play, are amongſt the moſt ſurprizing Works that Art ever yet form'd.

BUT

But before I quit this Account of the Water-Works of *Verfailles*, I muft not omit that noble Body of Water, call'd the *Ifle Royal*, placed in one of the Quarters of Wood in the Gardens there. It is about an hundred and thirty Toifes long, and fixty wide, as the Prints, fometime fince brought from *France*, intimate; and what makes it have the greater Effect to the Eye, is, that it is environ'd with Portico's and Hedges cut into Arch-Works, fhaded with a Row of Trees that accompany it; and at that End of it, which is next the Caftle, there is alfo another Piece, through which the Dauphin's Walk (as they call it) paffes, which Piece is adorned with the Statues of *Julia Mæfa*, *Venus*, *Jupiter Stator*, and *Julia Damna*, with Vafa's of white Marble by *le Fevre* and *Legeret*; and the great Piece is fet at the further End, with two Colloffes of *Hercules* and *Flora*, from the *Farnefe* Collection, being Copies from *Rome*, by *Cornu* and *Raon*.

The Canal is a thoufand Toifes long, and near forty wide; a Part of which, at the farther End, is an Eftang, or Bafin, of an hundred and eighty Toifes long, and an hundred Toifes wide, in which there is an old Ship fix'd; and the Crofs or Tranfverfe Canal, which makes it appear like a Crofs, is five hundred Toifes long, and between thirty or fourty Toifes wide.

The Fountain *de l'Encelade* is one of the chief Pieces of Water that is contain'd within the Wood-Works. The Figure the Water plays from, is a large Giant, four Times as big as the Life, out of which proceeds a large Gerb of Water, that plays feventy eight Foot high, encompafs'd with a vaft Number of Bouillons, that fpout out of the Hands, Feet, &c. the Defign of the famous *le Brun*, and the Jet made from the Model of Monfieur *Efparade* of *Marli*. The whole appears to be the moft beautiful of any enclos'd Piece of Water in the whole Gardens of *Verfailles*. To this may be added, the Bains *de Apollo*, a Piece of Groupe-Work in white Marble, wherein is placed the Goddefs *Thefis*, accompanied by fix Nymphs that are Servitors to her: On each Side of this large Groupe are two fmaller ones; in the Middle of which are the Courfers of *Apollo*, attended by *Tritons*. The Embellifhments of this expenfive Structure are many of them of Gold, and the whole being the Defign and Execution of four of the greateft Mafters of *France*, *Gerardon*, *Regnaudin*, *Guerin*, and *Marfi*, are in the Number of the moft curious Pieces of Art which that Palace produces.

The Water-Works of *Marli*, *Meudon*, and feveral other Places in *France*, are alfo very admirable, the contracted Cuts whereof I intended to have made a Part of this Work, but that I find them already done

done by Mr. *Bowles*, Printſeller in *St. Paul's Church-Yard*, where all thoſe of *Verſailles* may be had in Sets, and will not be improper Appendixes, for all Gentlemen who approve of it, to be put to the later End of this Treatiſe.

To proceed, we are no Way behind hand in *England*, though not in the great Beauty, yet in the Advantages that Water has procured to Trade, as well as for the Convenience of watering Cities, Towns, large Tracts of Meadow-Land, Upground, *&c.* by the raiſing of Damns, Wares, and the like; and by the cleanſing of navigable Rivers and Water-Courſes.

Remarkable enough, being that expenſive, but yet uſeful Work that ſupplies *Plymouth* with Water; "A Work (as the learned E-"ditor of *Camden* obſerves) which was done by the Contrivance, and "at the proper Coſt and Charge of that great Admiral and Diſco-"verer of unknown Countries, (at leaſt by a Relation of his,) of the "antient and noble Family of the *Cavendiſhes*, now Dukes of *Devon-*"*ſhire*, who brought to that Town a large Stream of Water from "a great Diſtance, through many Windings and Turnings, driving "many Mills, and ſerving for other neceſſary Uſes and Conveni-"encies of the Inhabitants."

The New River, that ſupplies the greateſt Part of *London* and *Weſtminſter* with Water, ariſing from the two Springs *Amwel* and *Chadwell*, near *Ware* in *Hertfordſhire*, appears to be a Work worthy of the vaſt Charge and exquiſite Skill of Sir *Hugh Middleton*, who in five Years Time, *viz.* from the Year 1608. to the Year 1613. conducted it through Fields and Meadows in a turning and winding Courſe for above ſixty Miles, before it reaches this rich and opulent City; in the Courſe of which the Channel is neceſſarily carried in ſome Places twenty Foot deep, and in other Places twenty Foot higher than the natural Level of the Ground, in Aqueducts or Troughs of Wood above Ground; and has over it in that Courſe eight hundred Bridges, ſome made of Wood, ſome of Stone, and others of Brick; the River feeding and ſupplying, by the Help of the Mill at *Iſlington*, all the lower Rooms, at leaſt in the higheſt Part, and the upper Rooms in the loweſt Part of that populous City. And, though the Water may not be ſo pure as if it were convey'd in Arches of Brick or Stone, as that of *Rome* was, yet by its being vented into a large deep Reſervoir, it is conſiderably ſettled and refined; and is a Work that few Cities of the World can boaſt of, and fewer yet excel: Nor would it be much to my Purpoſe, but would take up too much Room in the Compaſs I propoſe to allow myſelf in this Introduction, to take notice of all the other Methods whereby *London*

and its powerful Neighbour *Weſtminſter*, is ſupplied with Water; nor of thoſe Inventions that are every Day on foot for ſupplying of two Cities growing more populous and populous, and which, we may expect will, in a few Years, much excel the largeſt Cities of the World; ſome Account of which may be expected in the following Sheets, as what will help to give the trueſt Idea of this Miſtreſs and Metropolis of *Great Britain.*

To go on with our Hiſtory: The great Labour and Expence that has been beſtowed in the draining or drawing off the ſuperfluous Water in the Fens in *Cambridge* and *Lincolnſhire*, Iſle of *Ely*, and other Places, would ſwell this Introduction beyond its propoſed Limits, as would alſo the raiſing of Rivers and Carriages for the Overflowing of Meadow and Uplands in the ſeveral Counties of *Southampton*, *Wilts*, and *Dorſet*, eſpecially about *Sarum*, *Dunton*, *Winton*, and other Places. But I muſt beg leave to aſſume to myſelf the Credit of an Undertaking of this Kind, performed ſome Years ſince for the Earl of *Coningsby*, at *Hampton-Court* in *Herefordſhire*; which, though not brought above two Miles, may (conſidering the Difficulties that attended this uſeful, but expenſive Work) be reckoned amongſt ſome of the greateſt Undertakings that were ever attempted in this or any other Country by a private Purſe; yet, though the Coſt of it has been little leſs that 1200 *l.* it has laid a Foundation for the Watering of two or three hundred Acres of Land, that is, and may be very well improved from five or ſix Shillings, to twenty or thirty Shillings an Acre at leaſt.

This Work, begun and finiſhed in eight or ten Months, was conducted by many Windings and Turnings through high and almoſt impenetrable Rocks, ſome of at leaſt ten or fifteen Yards perpendicular, and over other Variety of Earth, Clay, &c. in a Drain or Carriage about five Yards wide; which emptying itſelf on ſome high Lands or Eminencies that lie above that antient Seat, waters all the Land thereabouts, and cauſes an uncommon early Verdure, and Profit to the Poſſeſſor, though much higher than the Top of the Houſe itſelf: Which I mention the rather in this Place, that it may incite other Noblemen and Gentlemen to the Proſecution of the ſame, wherever there is an Opportunity, the Recompence being at leaſt 20 *l. per Cent.* for their Money, clear of all Charges.

The Carriage that plays the Engine at *Blenheim*, and other Works of that Kind, done in ſeveral Places of *England*, have fallen to my Lot, with, I hope, the deſired Succeſs.

It muſt be confeſs'd that we are not yet arrived to that Grandeur in our Garden Water-Works in *England*, as they are in *France* or

3

or *Italy*, though the Advantages we have by Nature are as great or greater than any that are to be met with in other Countries. The *Villa de Medicis*, with its Water-Works, the Caſcade of the *Teverone*, with the famous Falls of the *Freſcati*, to omit many others, which are accounted by Travellers amongſt the greateſt Works that either Nature or Art are capable of furniſhing the World with; and, whoever reads the charming Deſcription that Mr. *Addiſon* gives of thoſe Works and the adjacent Country, will obſerve it to be a Subject, wherein not only Travellers and Poets, but the moſt ſkilful Painters in *Italy* and *Rome*, have employ'd themſelves to great Advantage.

Horace, (as Mr. *Addiſon* has it,) had his Eye upon it in the agreeable Touches he gives of thoſe beautiful Landskips,

Me nec tam patiens Lacedæmon,
Nec tam Lariſſæ percuſſit campus opimæ,
Quam domus Albania reſonantis,
Et pæceps Anio & Tiburni lacus & uda
Molibus Pomaria Rivis. Hor. lib. Od. vii. v. 10.

In *Engliſh* thus,

Not fair Lariſſa's *fruitful Shore,*
Nor Lacedemon *charms me more,*
Than high Abania's *airy Walls*
Reſounding with her Water-Falls;
And Tivoli's *delightful Shades,*
And Anio *rowling in Caſcades,*
That through the flowry Meadow glides,
And all the beauteous Scene divides. Addison.

And when they are made to appear by many Breaks and uninterrupted Scenes, made up of an infinite Number of an Inequalities that naturally ariſe from the agreeable Mixture of Hills, Groves, and Valleys, which there appear; and when its Stream is broken by ſuch a Multitude of Caſcades, that ſo often ſhift themſelves from one Channel to another, and after a very rapid and noiſy Courſe from Hill to Hill, at laſt to fall into the antient and celebrated *Tyber*, is a Deſcription that from ſo uncommon a Pen, carries with it ſomething that is ſtupendiouſly natural and great.

And it is agreeable to this, ſays our worthy Author, that we are to underſtand *Silius Italicus*'s Deſcription, to give it its proper Beauty.

Here the loud Anio'*s boiſterous Clamours ceaſe,*
That with ſubmiſſive Murmurs glide in Peace
To his old Sire the Tyber. ------

Addison's Works, Vol. ii. p. 129.

Of little leſs Beauty (but perhaps great Uſe and Account) to thoſe celebrated Landskips, though not in the Precipitancy of their Caſcade, yet in their natural Turnings and Meanders, are many of our Rivers in *England*, which when lying beneath (as many of them do) fruitful Hills, many of them cloathed with noble Amphitheatres and Coverings of Wood, claim a Share, if not the Precedence, of any Views yet mentioned.

For whoever yet beheld the River *Wye*, (on the Banks whereof has been the Reſidence of ſome of our antient Bards,) paſſing by many Windings and Turnings from *Roſs* by *Hom-Lacy*, the Seat of the noble Family of the *Scudamores*, to *Hereford, &c.* but muſt be extreamly ſurpriz'd at the Beauty of thoſe Voluta's it appears to make, adorned as it is with ſuch prodigious lofty and natural Amphitheatres of Beech and other Wood, reaching in Appearance to the Skies, in many Places a Quarter of a Mile high, and generally full of Springs. To this pleaſant Scene may be added that beautiful Hill facing *Hampton-Court* aforementioned, in that County, under which runs the River *Lugg*, forming a natural Semicircle, or Half-Moon, which by the Height of the Wood, the Agreeableneſs of the Verdure, may, I humbly conceive, be accounted amongſt the beſt determinate Proſpects any where to be ſeen.

Nor need we in all Probability give Place to *Italy* or *France* itſelf, in ſome artificial Caſcades and beautiful Falls of Water in *England*; thoſe of Mr. *Blaithwaites* at *Durham* near the *Bath*, of Mr. *Ernly*'s at *Whetham*, thoſe of *Chatſworth*, belonging to the great and noble Family of the *Cavendiſhes*, are worthy of Account: But what is more ſtupendious than them all, the Drawings of which I am endeavouring to procure, are thoſe fine Falls of Water belonging to Mr. *Aiſleby* in the North, with thoſe of *Bolton, &c.* To proceed in Nature;

The River *Avon* in *Hampſhire*, and adjoining to the new Foreſt, (remarkable for that eminent Danger from which *Titus* is ſaid to have reſcued his Father *Veſpaſian*, when cloſed beſieg'd by the *Britains*,) begins at *Charford-Farm*, (as *Camden* tells us, ſo called from *Cer-dick*,

dick, a valiant *Saxon*, that alſo gave the *Britains* ſo great a Defeat on the Banks of that River,) paſſes through many fine Meadows by *Folden* or *Forden* Bridge to *Ringwood*, *&c.* till it joins the *Stour* near *Chriſtchurch*, and has the Woods of the new Foreſt riſing like an Amphitheatre on the South, which gives ſuch an agreeable Proſpect to thoſe Seats that are ſituated on the North-Side, eſpecially *Breamore*, one of the Seats belonging to the Lords of *Brooke*, the Place from whence theſe Memoirs are dated; from which, through many green and delightful Meadows, and in View of Mountains, and woody Landskips, you ſee it take its Courſe till it falls into the Sea at *Chriſtchurch*, and is, as it were, loſt in the Surges of that voluminous and extenſive Ocean.

The *Avon*, another River of the ſame Name at *Warwick*, merits a Place in this ſhort Account of Rivers, as it paſſes by the Town and other riſing Grounds that lie contiguous to an antient and noble Caſtle, which is ſo great a Strength and Ornament to that delightful Town.

This Place, (if it be the ſame that *Camden* ſpeaks of,) is, in his Words, the Seat of Pleaſure it ſelf. There, or near to it, (perhaps that which is now the Lady *Bowyers*,) and which has this fine River in View, is (ſays he) a ſhady Grove and chryſtal Springs, moſſy Caves, Meadows, Ever-greens, ſoft and murmuring Falls of Water under the Rocks; and to crown all, Solitude and Quiet, the greateſt Darling of the Muſes, the Place where *Fame* tells us, (ſays that laborious Author,) the celebrated *Guy* of *Warwick*, after he had finiſh'd his martial Atchievements, built a Chapel, led a Hermit's Life, and was at laſt buried.

The River *Trent* leading from *Nottingham* to *Newark*, the *Severn* from *Glouceſter* to *Worceſter*, and ſo on to *Shrewsbury*, are both of them laſting Monuments of the Nobleneſs of our Rivers, and that they equal, if not excel, the ſo-much-talked-of *Tyber* and the *Sein*, as may the River *Lodon* and the *Thames* that of the *Danube* and *Mozelle*, if not in the Extent, yet in the Limpidity and Clearneſs of their Streams, ſo beautifully deſcribed by one of our *Engliſh* Bards.

Though deep, yet clear, though gentle, yet not dull;
Strong without Rage, without o'er-flowing full.

Durham's *Coopers-Hill.*

To finiſh this hiſtorical Account of Water-Works, to which the Delightfulneſs of the Subject has inſenſibly led me, let any one but take a View of thoſe that are at *Chatſworth*, *Bowden*, at Mr. *Brathwaites*,

waites near the *Bath*, juſt mentioned, and other Places, to which if you would add that which is newer, (and in ſome Reſpects nobler and greater,) thoſe of the late Duke of *Kingſton* at *Thoresby* in *Nottinghamſhire*, and of the new Lake at *Blenheim*, the Work of that Illuſtrious and Right Noble Lady, the preſent Dutcheſs *Dowager* of *Marlborough*, will ſee to what a Pitch practical Hydroſtacy is arriving to in *England*, and how we are like to emulate moſt of our Neighbours in theſe beautiful Embelliſhments.

AND to finiſh this; I conceive that the Canal and Caſcade at *Buſhy-Park*, the Draught of which I have hereto adjoin'd, the ſole Contrivance (I had almoſt ſaid manual Operation) of that truly ingenuous Nobleman, the then *Mæcenas* and Encourager of all Arts and Sciences, the late Earl of *Hallifax*, is, without doubt, one of the beſt Works of that Kind in *England*, and perhaps as good as any elſe where. And thus much I thought proper to ſay in Commendation of my own Country, (compar'd to others,) and as much as in me lies, to create ſuch a due Emulation amongſt my Countrymen, as may incite them to the Improvement of this natural and uſeful Beauty, which when added to the Fineneſs of our Turf, and the Nobleneſs of our Timber, may (as we are in many other Caſes) be the Envy of our Enemies, and the Delight of our Friends.

CHAP. II.

Of the Origin and Riſe of Springs, and of the Opinion of thoſe who aſcribe them to Air, Vapours, Dews, Rain, Snow, &c.

THE Original and Riſe of Springs, like moſt other Things whoſe Cauſes lie conceal'd, have met with a Multiplicity of confus'd and unneceſſary Opinions, by which Truth has been either ſtrangely diſguis'd or deliver'd in dubious and ænigmatical Terms, ſuch as has puzzled, rather than inſtructed thoſe whoſe Genius's have led them to the Study of this Part of Meteorology. On this Account it is that I have in this Eſſay endeavoured, what I can, to ſet this Matter in the cleareſt and moſt perſpicuous Light, and to fix the tedious and uncertain Accounts we have of Springs on ſome more rational Baſis, by giving Reaſons why thoſe Opinions which were delivered in the antient, as well as ſome modern Philoſophy, ought to be rejected.

FOR

For that of *Ariſtotle* and his Followers, who judge it to be from Air, included in the Caverns and Vaults of the Earth, and there by the conſtringent Cold of thoſe Receptacles condenſed into Water, is very unlikely, if not altogether impoſſible; for admitting there be (as a learned Phyſician in a Manuſcript I have ſeen on this Head has it) ſuch a Mutation of Elements, (which has often been diſproved,) if we conſider the mathematical Difference which there is between the Bulk and Proportion of the two Bodies of Air and Water, how vaſt muſt thoſe Caves be, which in its State of Rarefaction can contribute or contrive Air enough for the perennial Streams of a large Fountain? And though we ſhould allow them the ſame alternate and ſucceſſive Supplies which they impart to Water, yet we are to conceive, that they muſt be detain'd for ſome Time in thoſe Caverns before they are condens'd, and ſo not always *in Tranſitû*, as Water is.

Besides all which, (with *Marriotte*,) it is a dubious Point, even to be denied, that there are ſuch Caverns or hollow Places in the Ground capable of ſuch Performances, the Places from whence Springs proceed being generally compoſed of ſmall, gravelly, ſandy, or ſmall rocky Ground, thoſe Caves having never been actually, that I know of, diſcover'd; though by the iſſuing out of Springs from the Sides of Hills, they ought to be ſome where near at Hand, and therefore in all Probability have no Exiſtence, but in the Minds of their chimerical Inventors.

Besides this Opinion of the Peripateticks, there are ſeveral others maintain'd by Philoſophers of later Ages, as that of *Aquinos*, who held their Original to be from the Stars and celeſtial Influences. *Scaliger* thinks them to be from the Earth's preſſing of the Waters; and *Faber* from the Attraction of all Waters by the North Pole, by which being carried to the Centre of the Earth, they are thence, being firſt impregnated by the Virtues of the univerſal Spirit, diſpers'd into the ſeveral Channels of the Earth, all which hypochondraical Conceits dying with their Authors, have been but little noted: Thoſe of *Senectus Bartholinus*, and ſome later Writers, as *Plott*, *Hook*, &c. having much more Weight with them, there being nothing more conſentaneous to Reaſon, whether phyſical or mechanical, and the Analogy that naturally ſubſiſts between the Macrocoſm and Microcoſm, (in both which the Laws of Elaſticity take place,) than the Circulation and Aſcenſion of Waters in the Bowels, and on the Surface of the Earth, as the Blood does in the Body, or rather, as the Sap does in a Tree.

For

For if we take a Survey, and acknowledge any thing of that Nature which is in Animals and Vegetables, it will be eafily demonftrated, that Water ferves the Earth for the fame Purpofes, as the Blood does the Body, or the Sap the Trunk and Boughs of a Tree, and is elevated by the fame Means, namely, for the Irrigation of thofe Parts of it which are dry, and to reduce it to fuch a Confiftence as to be fit for the Impreffions of the univerfal Spirit, even as it fupplies the Nerves of the Body, or the Pores of the Tree, with thofe animal Spirits or rarify'd Juices which circulate in the Body, or afcend the Trunk of a Tree; it being by this conftant Supply of Spirits and rarified Juices, that both a Production of new Matter, as well as a Supply to what was before decay'd; and from the perpetual Afcenfion or Circulation of the liquid Matter therein contain'd, that the Motion, on which depends all the Actions of Vitability in both, is continued. And I muft confefs I have often wonder'd that fo many Philofophers, (and fome of them of a new Date too,) when they are fo curious in their Enquiries into other Parts of Nature, and fuppofe them to confift of fuch an innumerable Chain of Caufes, fhould refolve this great Point into the dull and lazy Laws of Gravitation and natural Propenfity, when its firft Source, Motion, and Afcent, is fo eafily accounted for by the new eftablifh'd and now fo-well-underftood Laws of Pulfion, as having its firft Source from the Sea, and being arriv'd through all the permeable Parts and fubterraneous Channels of the Earth, in a due Circulation and Afcent, (as it appears in all percolated and afcending Liquors,) either in a fwifter or flower Current, (according to the Largenefs of the Paffages in which it runs,) through thofe Veins, Channels, and Ducts of the Earth, till it breaks out of the Sides of the Hills, and traverfes its Way, even to its Return into the Sea again; from whence, according to the Opinions of fome of the beft Philofophers, both antient and modern, it had its firft Rife.

But to proceed to a ftrict Examination of fome of thofe erroneous Opinions that have long fubfifted in the hidden Caufe of Springs, there are * (as *Marriotte* in his Hydroftaticks, Page 15. of the *Englifh* Edition, by the Learned *Defaguliers*,) that give another Reafon for their Origin and Rife, attributing it to Vapours, and not Air,) which proceeding from the innermoft Parts of the Earth, meet with

* *Of this Opinion alfo is* Rohault, *one of the Chief amongft the* Cartefian *Philofophers, who* (Cap. x. Page 41. *of Dr.* Clarke's *Edition,*) *fays, that they are from Water diffolv'd into Vapour by fubterraneous Heat, which by its own fluid Nature is carried to the Tops of the higheft Mountains*, &c.

with Rocks which are on the Tops of Mountains in the Form of Vaults, do then become Water, as in a Still, and then run out at the Foot, or the Declivity of thoſe Mountains, in the Manner we ſee them; but this Suppoſition (ſays our ingenuous Author) can hardly be maintained. For if A, B, C, Fig. I. Plate 1. be a Vault in the Mountain D, E, F, it is evident, that if the Vapours ſhould become Water in the Concave of the Surface A, B, C, that Water would fall in a perpendicular Manner towards H, G, I, and not towards L, or M, and conſequently never make a Spring. Beſides, as it is elſewhere obſerved, it is denied that there are Hollows enough, if any at all, of a Capacity large enough to make ſuch Springs; and it can't be made appear (ſays *Marriotte*) that there are any ſuch.

If it be ſaid that there is Earth on the Side of, and beneath A, B, C, it will be anſwered, that the Vapours will guſh out at the Sides towards A and C, and that very little will become Water; and becauſe it appears that there is almoſt always Clay where there are Springs, it is very likely that thoſe ſuppoſed diſtilled Waters can't paſs through, and conſequently that Springs can't be produced, by that Means. And as to what ſome Authors tell, that Springs have ceaſed running, for having given Vent to great ſubterraneous Cavities, from whence there proceeded great Quantities of Vapours which became Water, *Marriotte* ſuſpects to be Stories. But it is not denied that there may be ſuch Diſpoſitions in the Tops of Mountains, and chiefly ſuch as are covered with Snow, (ſuch as the curious *Ray*, in his topographical Obſervations, Page 103.) mentions to be at the Foot of the *Alps*, where the Springs flow very ſparingly in the Winter; but in the Summer, and upon the ſuppoſed Diſſolution of thoſe Snows, in a luxurious Manner. But this is rarely to be met with in *England*, and can't be drawn into Conſequence as to other Springs.

The ingenious Dr. *Halley*, in his Account of Springs, publiſhed in the Tranſactions of the Royal Society for *January* and *February*, 1692.(and from him Monſieur *La Clerc*,) affirms, that Springs owe their Original to that great Quantity of Vapours which are drawn out of the Ocean by the Heat of the Sun; and after that, when the Sun departs the Horizon, deſcend again in the ſame great Quantities on the Tops of high Hills, Mountains, and other upland Grounds, (eſpecially amongſt the Tropicks, where it put his aſtronomical Inſtruments into a great Diſorder; and particularly, that his Paper was ſo very wet, that in a ſhort Time it would not hold Ink; adding, that thoſe Obſervations were made not only in *Europe*, but alſo in the Iſland of *St. Hellens.* And aſſerts farther from thence, the Manner how Springs may come to break out on the Tops or Sides of high

Hills, rather than below;) and that thofe Vapours are difperfed here and there by the Winds, and fo lodge themfelves rather there than on low Situations, finking down a little Way into proper Receptacles and Refervoirs, where gathering together, they break out in the Manner we fee them.

THE general Computation which that learned Author makes, as they are abridged by a very ingenious Hand, take as follows, extracted as it is from the *Philofophical Tranfactions*, N°. 189, 192. where from two Experiments he has endeavoured to make appear, that the Sun and Wind can't raife lefs than $\frac{1}{10}$ of an Inch Cubick of Water in a Day; each fquare Foot half a Wine Pint, every 4 Foot Square a Gallon, a Mile Square 6914 Tuns, a Square Degree, fuppofe it be 60 *Englifh* Miles, 33 Millions of Tuns.

AND if the *Mediterranean* be eftimated at 40 Degrees long, and 4 Degrees broad, it will be 160 Degrees Square of the Sea, and confequently will lofe in Vapours 5280 Millions of Tuns in a Day.

THE *Mediterranean* receives thefe confiderable Rivers, (*viz.*) the *Ebro*, *Rhone*, *Tyber*, *Po*, *Danube*, *Neifter*, *Neiper*, *Don*, and the *Nile*; and we will fuppofe each of thefe 9 Rivers to bring down ten Times as much Water as the *Thames*, to wit, from a Calculation there made of 1827 Millions of Tuns in a Day, will be brought into the *Mediterranean* by the Rivers running into it, which is little more than what is proved to be raifed in Vapours from the Sea in that Time, one Part falling back again into the *Mediterranean* in Rains and Dews, and the remaining Part is fupplied by the Current conftantly fetting into the Straits at *Gibraltar*. Hence likewife appears the Reafon of the *Cafpian* Sea's never overflowing at all, tho' it receives fo many large Rivers, yet fends forth none, as much being carried off in Vapours as the Rivers fupply.

NOW if an Atom of Water be expanded by Heat into a Bubble, ten Times bigger than it was in its natural State, fuch an Atom would be fpecifically lighter than Air, and rife continually, till the Warmth declining, and the Air growing cooler, and withal fpecifically lighter, the Vapours confequently fhall ftop, or defcend at a certain Region of the Air. Next confider the Earth's Surface, as interfperfed with high Ridges of Mountains, to which, when the Vapours are carried by the Winds, they are compelled by the Stream of Air to mount up with it to the Tops of thofe Mountains, where being precipitated by the Cold, it gleets down the Crannies of thofe Stones, and uniting, forms fingle Springs; the Union of feveral of which forms Rivulets, many of which joining together form Streams, fuch as the *Danube*, &c. which latter, one would hardly think could

be

be compoſed of Vapours, were it not conſidered at the ſame Time what vaſt Tracts of Land that River drains; in Proportion to which, and for the aforeſaid Reaſon, we find Rivers great or ſmall. From this Hypotheſis likewiſe appears the final Cauſe of Hills, which ſerve for Alembicks to diſtil Waters for the Uſe of Man and Beaſt.

But for a more particular Account how this great Work of Nature is performed, and how thoſe Vapours are raiſed from the Sea, the Explanation of the following Plate does more clearly demonſtrate.

These Vapours then which are raiſed from the Sea, from P, to g, and F, may be thus accounted for. Let Fig. II. Plate I. repreſent the Globe of the Earth, to P, Q, R, S, ſurrounded by the Air, as far as B, A, D, which being heavy in it ſelf, and thereby capable of being compreſſed, grows continually finer from below at P, upwards through g, and F, to B, and conſequently lighter, becauſe its elaſtick Faculty dilates it more in Proportion, as the Preſſure of the Air is diminiſhed; and as it ſcatters the Particles of Air from each other, renders it lighter in an equally enlarged Space. And if we now ſuppoſe farther, that this ſame Air is heavier below at that Part of the Globe which lies between F and P, and lighter above between F and B, than the Water evaporated or mingled with Fire, ſo that about F, G, H, the ſaid Air is of equal Gravity with it, it will follow from what has been juſt now mentioned, that the Vapours between F and P will aſcend; that being raiſed to the Bounds of the Equilibrium F, G, H, they will float like Clouds at I, and I, G; and being equipoiſed, will neither riſe nor fall; but when raiſed higher to B, I, or H, D, they will deſcend.

This demonſtrates how Vapours are rais'd from the Sea from P, to g, by the Warmth of the Sun; as alſo how they are enabled to float in thin Air, as in different Stages and Degrees of Height as g, K, d, and F, I, G: And, moreover, why the ſaid Vapours being rais'd higher up to Z by the Winds, or driven againſt one another by contrary Winds, and for other Reaſons do deſcend in Rain, Snow, and the like.

But Dr. *Halley* ſubjoins another Manner to theſe, namely, that a floating Vapour or Cloud in E, being driven againſt the Mountain Q, N, R, by the Winds at E, aſcends to the Top N, and there being got into a lighter Air, cannot be any longer ſuſtained, but falls down in ſmall Drops upon the Head of the Mountain, and from thence running down, fill the Cavities of the Mountains, (which contrary to the Opinion of *Mariotte*, and others, are ſuppoſed to be found there with Water, and ſo continually running down through the Orifice at M, produces the little Brooks m, e, F, or M, e, V;

which joining themſelves with others of the ſame Nature, form a large River.

By this Way it appears then, (ſays my Author,) why the Waters are aſſembled in greater Quantities upon the Mountains, than below; for as much as their Tops from Q, R, to N, againſt the Winds which drive the Clouds m, E, K, d, *&c.* they ſerve for Barricadoes, or Croſs-trees, and ſo do either force the Vapours to aſcend into a ligher Air, or forcing them againſt thoſe Tops, ſqueeze them together, whereby they become heavy, and fall down again.

Now theſe Vapours (ſay our Naturaliſts) are condens'd by the great Shadows which theſe Monntains produce, and which occaſion a continual cold Air about them, even in the hotteſt Seaſons, as is ſeen in the Extract of the Hiſtory of *Bohemia*, *Act. Lipſ.* 1682. Page 244. And on ſome Places, even on the *Alps*, in *Italy* it ſelf, where the Snow has been known to remain for ſixteen Years together, the old being of browniſh Colours, by which they were diſtinguiſhed from later Snows, which were white and clear.

Suppose then the Sun to be at O, Fig. II. of the following Plate, where the Mountains Q, N, R, caſting its Shadow, as Q, E, X; there the Sun-Beams are hindered, either by Mountains lying about it, or becauſe the Sun ſhines ſeldom upon that Side, from ever heating the Air to ſuch a Degree, as is found in the next adjacent Air. It is plain then that the Air within the Shadow Q, E, X, will be a great deal colder than that which encompaſſes the Mountain out of the Shadow. And this is the Cauſe of the Condenſation, and conſequently the heavy Deſcent of theſe Vapours, now ſuppoſed to be turned into Water. And to ſhew how the Sea is diſpos'd to emit ſuch a Quantity of Vapours as are neceſſary for the above mentioned Purpoſes, the learned *Halley*, in his *Philoſophical Tranſactions* for *September* and *October* 1688, has ſet down an Experiment made in a Veſſel full of Water, 4 Inches deep, and 7 Inches $\frac{9}{10}$ in Diameter, where having warmed the Water to ſuch a Degree as he ſuppoſed the Air might be in ſome of the hotteſt Months of the Year, by weighing, he found that there was almoſt a Quarter of an Ounce evaporated in about an Hour's Time, altho' there was little or no Reak or Smoke; neither did it upon the dipping in of the Finger appear to be hot: From which it may be calculated, that in 24 Hours Time, there would be 6 Ounces evaporated out of that ſmall Superficies. The *Oxford* Society have carried this Experiment yet further, and have ſuppoſed, that a Cubick Foot of Water weighs 76 Pound, which Foot containing 1728 Cubick Inches, and divided by 76, gives an Ounce and 13 Grains, which is the Weight of an Inch,

Inch Cubick of Water, the Weight therefore of 233 Grains, is as $\frac{233}{253}$ or thirty five Parts of a Cubick Foot.

THE Area then of a Square, whoſe Side is ſeven Inches and upwards, is forty nine, by which if you divide the Quantity of Water, which it is carried off in Vapour, *viz.* $\frac{35}{38}$, the Product is $\frac{35}{862}$, or $\frac{1}{53}$; from which appears, that there was fifty three Parts of an Inch carried off in that Experiment, and is as plain a Demonſtration as ſuch an Experiment will produce. How great a Quantity of Vapour may be exhal'd from Bodies of Water, which are larger (enough to ſupply, as may be inferr'd from that learned Author) when the vaſt Extent of the Ocean, and other watery Bodies, are conſider'd, not only Rains, Dews, *&c.* but alſo all large Springs when they lodge themſelves on the Tops of Hills and Mountains, as has been deſcribed in the Paragraphs before going.

THUS have I, with as much Induſtry and Perſpicuity as I could, ſumm'd up the Opinion of this great and learned Man, being unwilling to take upon me to overturn what he has thus judiciouſly ſet down. However, that I may purſue my intended Method, I muſt, with all who have conſider'd any thing of the great Effects which Vapours produce in many Parts of the World, own how largely they contribute to the Formation of Rains and Dews, in ſo much that we are told by Mr. *Warren*, in the *Act. Lipſ. Page* 98. That the Clouds and Fogs hanging over and about the Mountain called the *Pike of Teneriffe*, do run down every Day about Noon in ſuch vaſt Quantities, that they do abundantly ſupply the Place of great Rains, which never fall upon other Parts of that Iſland: And the ſame is confirm'd by the learned Doctor himſelf, who concludes from what he had before laid down on that Head, what great Quantities of Water muſt be collected in a little Time on Mountains which are larger; ſuch as the *Pyrennees*, the *Alps*, the *Apenine*, and *Carpathian* Mountains in *Europe*; the *Taurus*, *Carcaſus*, and *Immaus*, in *Aſia*; with others of great Note in *America.*

BUT although Vapours have ſo great an Effect, as to ſupply ſome of thoſe Parts of the World ſo plentifully, that they have no Occaſion of Rain itſelf, yet common Experience tells us, that in *England*, at leaſt, there is no ſuch Thing; nor do Vapours contribute much (if any thing at all) to the furniſhing of Springs or Brooks; nor are they to us of any other Uſe, than that by their Sublimation into the upper Regions of the Air, being there condenſed into Rain or Dews, they deſcend, and fall down gently again: Nor was it ever obſerv'd, that the thickeſt Dews, Fogs, or Vapour that ever fell with us, did at any Time enter ten Foot into the Ground, or do

any other than lodge itſelf in woolly hairy Subſtances, on the Surface of the Earth: Beſides where ſuch large Caverns are to be found, as deſcrib'd by the learned *Nieuentyl*, *Fig.* II. of the next Plate, is (amongſt all the caverous Obſervations which we have made) hard to be found; and if Rain does not contribute to the Original and Enlargement of Springs, (which ſhall be, in its proper Place, prov'd it does not,) how is it poſſible that Vapour or Dews ſhould do, (eſpecially in *England*,) where their Strength is not ſo great as it is in foreign Regions.

Besides, it muſt be ſuppos'd that all Vapour and Miſt falls (as Rain does) againſt one Hill, as well as another; and why then ſhould not the Hills in *Salisbury Plain* emit the ſame Quantity of Springs, as other Countries. More than that, there muſt be great Quantities of Vapour; and it ought to be continual, and immediately ſucceeding one another alſo, to ſupply the Streams of a perenial Fountain, which runs ſtronger in the Winter, when few or no Vapours fall only in Rain, (and when there are few or none of thoſe repeated Exhalations,) than it does in the Summer, when they abound moſt; ſo that if theſe Vapours contribute any Thing towards the Supply of Springs, it muſt be in mountanous and woody Countries, where lodging on the Summits and Tops of the Trees and Hills, they liquate and run down into the Chaſms of the Earth, and after that break out, and diſperſe themſelves for the Uſe and Benefit of Mankind, in the Manner ſo often deſcrib'd.

The Curious Monſieur *Marriotte* (with ſome others of our own Country) are of the Opinion, that Springs have their Riſe from Rains only, and produce Experiments, wherein, by Calculation it appears, that the Rains which fall in a Year, are more than enough for the Supply of Springs; one of which he tells us was made at his Requeſt by a skilful Man at *Dijon*, who plac'd near the Top of his Houſe a ſquare Veſſel of about two Foot Diameter, at the Top of which there was a Pipe, which convey'd the Rain that fell into it into a Cylinderick Veſſel, where it was eaſy to meaſure it as often as it rain'd; for when the Water was in the Cylinderick Veſſel, there was very little exhal'd for five or ſix Days.

The Veſſel of two Foot Diameter, was ſuſtain'd by a Bar of Iron, which advanc'd above ſix Foot beyond the Window whereon it was placed, and ſo fixed that it might receive only Rain-Water which fell immediately upon the Breadth of its opening, and that there might not any enter but what was to fall according to the Proportion of the upper Surface. The Reſult of theſe Experiments was,

that in a Year there might commonly fall in Rain-Water, to the Height of ſeventeen, (though others of our own Country ſay nineteen Inches,) as does the Anonymous Author of a *French* Book (mentioned by *Marriotte* and Dr. *Plott*,) entitled, *De l'Origine des Fontaines*, by Experiments which he had made three Years ſucceſſively.

But let it be ſuppoſed (with *Marriotte*) that leſs than theſe Obſervations, and that in a Year there falls Rain only to the Height of fifteen Inches. Upon this Suppoſition there would fall upon a Fathom in a Year forty five Foot Cubick of Water; and ſuppoſing that a League contains 2300 Fathoms in Length, and that a ſquare League contains 5290000 ſuperficial Fathoms, which being multiplied by 45 (the Number of Cubick Feet that fall upon a Fathom in a Year,) the Content is 238050000 Cubick Feet, which according to *Engliſh* Computation, is about 2380500 Hogſheads, ſuppoſing that ten Cubick Feet *French* of Water makes a Hogſhead, which it does, and more.

Again, *Marriotte* obſerves, in Relation to the Strength of Springs, that the Content of the whole Extent in Land, on the *Sein* and other Rivers, is ſixty Leagues in Length, and fifty in Breadth, which makes 3000 ſquare Leagues, the Product of which being multiplied by 238050000 amounts to 714150000000 Cubick Feet, which being divided by 10, as before, amounts to 71415000000 Hogſheads *Engliſh*, which the Lands that furniſh the Waters of the *Seine* at *Paris* receives from the Rain in one Year.

Now as to the Expence of this Water, *Marriotte* calculates it in the following Manner: The *Seine*, ſays he, above *Pont-Royal*, when it touches the two Keys, covering but very little of the Extremity of Land on both Sides, for about the Breadth of four hundred Foot, and five Foot deep in the Main, is then in its mean Bulk; and its Velocity at the Surface is ſuch, that it goes 150 Foot in a Minute, but it goes 250 Foot when the Waters are at their greateſt Height; for a Stick which is carried in the Middle of the Stream, goes as ſwiftly as a Man who walks very faſt, which may be ſaid to be 15000 Foot in an Hour, and conſequently 250 in a Minute, which is full four Foot in a ſecond. But becauſe the Bottom of the Water does not go ſo ſwift as the Middle, nor the Middle ſo faſt as the upper Surface, (as will be hereafter proved,) let it be ſaid that its mean Velocity is 100 Foot in a Minute.

The Product of 400 Foot, which is the Breadth, being multiplied by five, the Middle or mean Depth gives 2000; for it is eight or ten Foot deep in ſome Places, in others ſix, three, or two, and the Pro-

Product of 2000 by 100, makes 200000 Cubick Feet; and conſequently there paſſes through a Section of the Bed of the River *Seine* above *Pont-Royal* 200000 Cubick Feet in a Minute, 12000000 in an Hour, 288000000 in twenty four Hours, and 105120000000 Cubick Feet, or 12000000 Hogſheads *Engliſh* in a Year, which is not the ſixth Part that falls by Rains and Snows, which as has been before calculated, is 714150000000 Cubick Feet, or 71415000000 Hogſheads *Engliſh* in a Year.

It is plain then (ſays our very curious Author) that if the third Part of the Rain-Water was to be exhal'd up in Vapours immediately after it fell, and if half of the reſt was to remain ſome Time upon the Surface of the Earth to keep it wet, as it ordinarily happens, and ſome in the ſubterraneous Places under great Plains; and if only the Remainder ſoak'd in through little Conducts to make Springs underneath, or upon the Declivity of a Hill, there would ſtill be enough to produce thoſe Springs and Rivers as they now appear; and if you take eighteen Inches inſtead of fifteen in the above mentioned Calculation, you will have inſtead of 714000000, the Sum of 856980000000 Cubick Feet, or 85698000000 Hogſheads, which is eight Times as much as is expended in the Current of the River *Seine*.

From all which appears, the great Poſſibility there is that the Original of Springs may be from Rain, Snow, &c. But yet as ſpecious as it appears to be, there are a great many Objections to be brought againſt it, ſome of which I ſhall name in their Courſe: As, firſt, that if Rains be the Occaſion of Springs, how comes it to paſs, that ſome very large Tracts of Lands, ſuch as we have in the Weſt of *England*, have but few, and ſome but very ſmall Rivulets and Streams of Water, whilſt others more Northward, abound in very large Rivers, there being no Rivers, either in *Hants*, *Wilts*, or *Dorſet*, I may add *Somerſetſhire*, that are comparable to the *Trent*, the *Humber*, or the *Severn*, though the Tracts of Land that are to ſupply them, are much larger than in any of theſe Countries. And it is generally obſerved, that theſe Weſtern Counties produce as much or more Rain than any other Counties of *England* do, on Account of their being ſituated ſo near the Weſtern, or *Atlantick* Ocean, which produce ſuch Varieties of Wind, Rain, &c. And indeed the Obſervation is ſo general, that the largeſt champain Countries produce the leaſt Springs; whilſt others of leſs Amplitude, ſuch as *Glouceſter*, *Salop*, *Nottingham*, and other Counties, produce them in much greater Quantities.

The

The Reverend and Ingenious Mr. *Deerham*, whoſe Works are now ſo juſtly admired, on Account of the Accuracy of his Style, and the Curiouſneſs of his Obſervations, in his *Phyſico Theology*, Page 50. (amongſt many other ſtrong Reaſons, concludes from the Perennity of divers Springs, which always affords the ſame Quantity of Water, that Rains can have little or no Effect, nor do they contribute much, if at all, to Springs. And of theſe Sort of Springs, he tells us, there are many to be found every where, but particularly ſingles out one in the Pariſh of *Upminſter*, where he lived.

This in the greateſt Droughts was little, if at all diminiſhed, altho' the Ponds all over the Country, and in adjoining Brooks, (which had really their Original from Rain and Land-Floods,) were dry for many Months together; as particularly in the dry Summer Months of the Year 1705. And in the wetteſt Seaſons, ſuch as the Summer Months, and others, which preceded the violent Storm in *November* 1703. (*See Philoſophical Tranſactions*, N°. 289.) it was not obſerved, that there was any Increment of its Stream, excepting only from the violent Rains falling therein, or running down from higher Lands thereinto; which diſcoloured the Water ſometimes, and made an Increaſe only for a Day or two, or ſometimes but of a few Hours Continuance. But now if that Spring had had its Origin from Rain and Vapours, there would have been ſuch an Increaſe and Decreaſe of the one, as there ſhould happen to be of the other; as it actually is, in ſuch temporary Springs, as have their undoubted Source from Rain, Snow, *&c.*

But beſides this, there was another conſiderable Thing in the *Upminſter* Spring, (as it is in a thouſand others;) which was, that it breaks out of ſo inconſiderable a Hillock or Eminence of Ground, that can have no more Influence in the Condenſation of Vapours, or the Dropping of the Clouds, (which the Maintainers of this Hypotheſis ſuppoſe,) than the lower Lands about it have. By ſome critical Obſervations which were made by this curious Obſerver of Meteorology with a portable Level, his Houſe ſtood 80 or 90 Foot higher than the lower Water-Mark in that Part of the River *Thames* which was neareſt to him; and that Part of the River being ſcarce thirty Miles from the Sea, he gueſs'd (and was afterwards more fully convinced of it by Experiments) that he could not be above 100 Foot above it: The Spring he judged to be nearly with, or but little higher than where his Houſe ſtands; and the Lands from whence it immediately proceeds, about 15 or 20 Foot higher than the Spring; and the Lands above that of no remarkable Height. And, in-

indeed, by actual Meaſure, one of the higheſt Hills in that County was but 393 Foot high; and by other Experiments he was convinced, that neither that nor any other Land in *Eſſex* was above 400 Foot above the Sea. Now what (ſays my learned Author) is ſo inconſiderate a Riſe of Land for the perennial Condenſation of Vapours? or, I add, ſuch a ſmall Hillock as is before deſcribed, for the Maintenance even of ſo inconſiderable a Fountain as what was juſt mentioned? or indeed the whole County, to the maintaining of ſo many Fountains or Rivulets as are there found? But tho' that ſhould be allowed to be poſſible by the Calculations before mentioned, yet how ſhould it come to paſs, that that and other Springs, ſhould keep on in one conſtant and uniform Courſe, not increaſed by great Rains, nor decreaſed by dry Weather, (if Rain alone was the Origin and Cauſe of them,) is hard to conceive.

But this is not all, there being other Objections that offer themſelves againſt this Hypotheſis of *Mariotte*, and his Followers: One of which is, That though the Rain that falls in or near the River *Seine*, &c. does (as appears by Calculation,) ſufficiently produce Water enough to ſupply that River; yet there are other Places where the Springs are ſo large, and where there is no ſupereminent Ground, that 'tis impoſſible that they can have their Original therefrom. *Jo. Bapt. Ricciolus in Almegiſto novo*, *Lib.* II. *Cap.* 13. as quoted by Doctor *Plot*, Page 74. of his Treatiſe *De Origine Fontium*, tells us, that there flows into the *Adriatick* Sea in one Hour, 18000000 Cubick Paces of Water; which if he means, as he certainly does, Geometrical Paces, which are five Times the Quantity of our Cubick Feet, it makes 90000000 Cubick Feet, which is near eight Times the Quantity, that according to *Mariotte*, the *Seine* gives: And this River, ſays my often quoted Author, is ſcarce to be compared to the *Thames*, or the *Severn*, or even the *Rhone* in *France*, which is (it is to be ſuppoſed) a great deal larger than the *Seine*, which makes but a poor Figure compared to our *Thames* at *London*, or the *Severn* towards *Briſtol*, as the Maps demonſtrate. This, I ſay, ſhews the Inequality, at leaſt, that there is in the Fluxion of Springs in different Places, though there are, or may be Lands of equal Superficies to ſupply the one as well as the other. And certain it is, that there are Lands very large and voluminous, where there are few or no Rivers at all; and in other Places prodigious large Rivers, where there is no ſupereminent Ground, the *Danube* it ſelf riſing, as ſome Authors affirm, in the Middle of plain Fields. But of this, more elſewhere.

Farther, that Rains have little or nothing to do in the Original and Riſe of Springs, I take from the following Obſervation, which I my

my ſelf have lately made at *Chelmsford* in *Eſſex*, where there is one of the moſt conſtant and fineſt Springs I ever ſaw, eſpecially in a Town.

At the Conduit, which is in the Market-Place, there are three Pipes, from which the Inhabitants fetch their Water: Theſe three Pipes, ſupplied, as they are, by a five Inch Main, emit one Hogſhead and half and four Gallons in a Minute, 12272 Hogſheads and 48 Gallons in one Day, 69469 Hogſheads three Gallons in a Month, 830191 Hogſheads 39 Gallons in a Year. This Account was taken in the Summer, when the Pipes might be ſuppoſed to afford leſs Quantities than in the Winter.

Accordingly it is obſerved, that when another Spring, which lies ſomewhat above the other, ſends out its Water, which it does about the Autumnal Equinox, which this Year 1727 happens about the Fourth of *October*, and is the Occaſion why the Coronation of his preſent Majeſty King *George* the Second, is deferred till the 11th of this Month, that then by the Union of the Spring above it, the Conduit will run half a Hogſhead in a Minute more than it did before.

Now the Reaſon of this Spring's being dry, at leaſt, that it does not afford much Water in the Summer, and ſo great a Quantity in the Winter, is with great Probability of Truth owing to the Lowneſs of the Tides all the Summer: For as for Rains, let them happen to be never ſo great, they never enlarge the Quantity of Water the Springs ſend out in the wetteſt Summer; nor does the Spring give any Thing leſs in thoſe Summers which are the drieſt: So that it appears plain enough, that it is the high Tides which happen at that or any other Time of the Year, which gives Birth to that uppermoſt Spring, according to the Height of the Sea, and the Gravitation of the Atmoſphere. And this is the Opinion of the Inhabitants who have long obſerved it.

As to the Manner how Waters are raiſed up into Mountains, and other high Lands, and which has all along puzzled ſo many great Men, (Mr. *Deerham* ſays,) may be conceived by an eaſy and natural Repreſentation, made by putting a little Heap of Sand or Aſhes, or a little Loaf of Bread, into a Baſon of Water, where the Sand will repreſent the dry Land, or an Iſland, and the Baſon of Water the Sea about it; and as the Water in the Baſon riſes up to or near the Tops of the Heap in it, ſo does the Water of the Sea, Lakes, &c. riſe in Hills: Which Caſe he takes to be the ſame with the Riſe of Liquids in capillary Tubes, or between contiguous Plains, or in a Tube fill'd with Aſhes; of which the induſtrious and compleat Artificer in Air-Pumps, Mr. *Hawksbee* has given ſome not contemptible Experiments in his *Phyſ. Mechan. Experim.* Page 139.

which ſhall be exhibited in their proper Places, and proceed to the farther Examination of theſe and other Hypotheſes which lie before us.

Rohault, in his *Phyſicks*, Part III. *Cap.* 10. in his Account of Springs, ſays, That tho' one can't think of their Original without Admiration, yet that the Enquiry was not very difficult.

For if we conſider, (ſays he,) firſt of all, that there are few or no Springs which ever grow dry, and that Rivers, which are compoſed of thoſe Springs, are continually flowing into the Sea; it is eaſily inferred, that the Sea ſupplies all thoſe Fountains with Water by the ſubterraneous Streams which ſhe diſtributes through all the Veins and Pores of the Earth.

If (with this ingenious Author) we come to a more particular Account of the Manner by which this Water may be brought to Fountains, it is certain, that the exterior Part of the Globe is divided into an infinite Number of Channels, through which it is eaſy to be conceived, that Water may, by its own Gravity, and the Fluidity of its Nature, ſpread it ſelf even from Places of the greateſt Diſtance from the Ocean.

It is viſible, (ſays he,) that all ponderous Liquors, when they are included in great Veſſels, collect themſelves into a Level, and no Part of them can be higher one than another. The Sea Water in *Burgundy* and *Champaigne* for Example, out of which the Fountains of the *Seine* ariſe, and of which that River is compoſed, which empties it ſelf at *Havre de Grace*, being all on a Level; it is plain that that Water can't be raiſed any higher; and yet when the Countries before mentioned, where theſe Springs ſpread themſelves by the Declivity of the Courſe of the ſame *Seine*, are higher in their Superficies than the Sea, there are ſmall Veins of Water which belong and ſend the Water to thoſe which lie higher; and for that Reaſon muſt, by ſome Means or other, riſe much above the Height of the Superficies of the Water therein. It therefore remains, that we find out the Method by which Water may be raiſed from thoſe low Caves into the Tops of Mountains; all which ſhall be done in its proper Place. And to proceed:

Having thus traced the Opinions of many Authors, both antient and modern, with their Arguments *pro* and *con*, as to the Original and Riſe of Springs, it appears that ſuch is the different Sentiments which they are of, that it is ſtill ſomething of a Doubt from whence it is that their real Source is: I come now to what I have all along chiefly aimed at, and which, with humble Submiſſion to better Judgment, I take to be the true Original of all Kinds of Springs, after having ſumm'd up all that has been ſaid on this Head; as, firſt, That

That it can't be from Air, (as *Ariſtotle* and his Followers would have it,) nor from Vapours, either from above or below, (as the *Carteſians*, and ſome of our own Countrymen have ſuppos'd,) it being a Truth even to be denied, that are any ſuch Caverns, or if there are, that there is ſuch a ſudden Mutation of Elements, or that either of them ſhould afford Quantities of Water ſufficient for the Supply of ſuch large Fountains, which are found in many Places, in a regular and uniform Succeſſion.

That their Original is not ſolely, if at all, from Rain or Vapours, (as *Marriotte* and others have ſuppos'd,) has been made appear by that curious Obſerver of Meteorology Mr. *Deerham*, whoſe Obſervations thereon are exact, and beyond all Diſpute; and that there are many Hills and large campanious Countries in *England*, and other Parts of the World, though the ſame Quantity of Rain and Vapours fall on them which do on others, yet they afford few, if any Springs at all; a certain Indication that the Rains which fall on thoſe voluminous Tracts of Earth, are chiefly drank up by the Herbage, or dry Soils of thoſe Plains, and don't contribute (if at all) to the Increaſe of perennial Springs.

Besides all which, and to the Reaſons before ſet down, that neither Air nor Vapours, nor Rain can be the Cauſe of Springs, I add what Experience every Day ſhews us; and that is, in the Digging of deep Wells through thoſe almoſt impenetrable Rocks and Beds of Clay and Chalk, with which Well-Diggers generally encounter. A noble Lord, with whom I have the Honour to be very well acquainted, in *Glouceſterſhire*, has been ſome Time in digging one of them; and by all the Obſervations the Diggers could make, they would be oblig'd to go above a hundred Yards deep before they came to Water. Now, if Vapours from above, or Rain, were the Original of thoſe Springs, they would, according to the Hypotheſes of its Authors, ſubſide, and break out on the Tops or Sides of the Hills thereabouts, there being at leaſt three or four thouſand Acres of Land which lie on the ſame Level that this Well is, near a thouſand Acres whereof are Wood, the Top or Surface whereof being alſo a looſe rubbelly Rock, and ſo conſequently poſſeſt of all thoſe Properties which *Marriotte* recommends as conducive to the forming of good Springs, to the Maintenance and keeping up of which thoſe impenetrable Rocks, with ſome Strata's of Clay, that are generally intermix'd with them, are conducive alſo; I mean in the ſuſtaining them upwards towards the Surface, and obliging them to break out there: But more certain it is, that thoſe heavy Rocks, and Beds of Clay, Chalk, *&c.* depreſs ſuch Springs in their Aſcent, and is the viſible

Cauſe

Caufe why all Earths which abound with Materials of fo clofe a Contexture, never afford much Water, if any at all; and it muft be obferv'd alfo, that the Scarcity of Springs which is in many Weftern Countries, where there are greater Plenty of Rains from the *Atlantick* Ocean, than are in others more Eafterly or Northward, muft be owing to this Caufe.

To this Account of Springs not arifing in Plenty in Countries where much Rain falls, being drank up by the Herbage, Trees, *&c.* may be added, that there are other Places where they abound, having little or no Rain at all, particularly in the two Iflands of *Maio* and *Rotunda* in the *Ionian* Sea, in the *Thracian Bofphorus*, and other Places, where, according to the Account of the very ingenious Sir *James Young*, of *Plymouth*, as we find it in *Hook's Lecturas Cutlerian. de Potentia reftitutiva, p.* 28. it did not rain for a long Time, yet the Springs ran freely all the while.

To this may likewife be added what Dr. *Plot*, in his *Treatife de Origine Fontium*, obferves, that Springs have not their Original from Rain, as many would make the World believe; for that the nearer you go to the Sea, the more brinifh and falt, and the farther you go off, the fweeter Springs are. This is an Obfervation to be found not only in *Hieron. Cardani's Treatife de Subtilitate*, (of which more by and by,) *lib.* 2. *p.* 166. *Edit. Bafil. Anno* 1582. but alfo by Sir *James Young* elfewhere mentioned, who was curious in Obfervations of this kind: For which fee *Hook's Lecturas Cutlerian. de Potentia reftitutiva, p.* 31. The fame may be alfo difcover'd by any Gentleman who travels towards any of our maritime Ports, fince the nearer you come to them, the more brinifh and falt they are, and fo brackifh and bad, that within a Mile or two, and fometimes a farther Diftance, even fix or feven Miles, the Water is fo unfavoury, as that an Inlander, who is not us'd to them, can by no Means relifh them; and their Malt-Liquor in particular, is fo effected by it, that it is undrinkable by any but thofe who are continually us'd to it. Some particular Springs, indeed, there are, which are fweet; but they are in all Probability fuch, whofe Canals proceed from fome diftant Hills, it being often found that good and bad Springs are found nearly contiguous to one another. But this can't be drawn into Precedent, nor fufficiently maintain the Hypothefis of thofe who aver, that Springs derive their Origin from Rains, *&c.* And if it be made appear, as I think it is, that cold Waters are not produc'd by Rains, much more will it appear that hot Water, and thofe which are falt and bitter, cannot.

CERTAIN it is, upon the undoubted Credit of very worthy Men, that there are not only Springs but Rivers of that Kind, as * *Peter Martyr*, in a Treatiſe of his, ſets down, of a River in the *Weſt Indies*, which is ſo large, as that a large Veſſel may ride upon it; and in the mean time, it is ſo hot, that you can't touch it with your Finger. Of the ſame Kind alſo there is a Fountain in *Iſlandia*, as the aforeſaid Doctor has it, ſo hot, that no Fire can make it hotter. Another alſo of them is in the Iſland *Japan*, which, as *Caronius* witneſſes, is three Times hotter than 'tis poſſible any Fire can make it, as † *Varennius* in his Geography ſets down.

BUT it is needleſs to go far for Examples of this Kind: Thoſe whoſe Misfortunes lead them to the Hot Baths of *England*, and other *European* Countries, are Witneſſes of the Truth of what I am here aſſerting, I mean as to their Heat, which though not ſo large and extenſive as thoſe before mentioned, yet is equal to what a moderate Fire will do. Let then thoſe Advocates for the Production of Springs by Rain, tell us, how it comes to paſs, that one Spring is ſo hot, another ſo bitter, and a third ſo ſalt, that it is impoſſible for any Body to uſe them with Pleaſure. Can they proceed from Rain, or any other ſuperficial Cauſe? or is there any Reaſon to believe they can receive, or be endued with any of thoſe Properties by any other Means than by their ‡ Aſcent, and Percolation through thoſe Veins of Earth that gives them thoſe ſaline, fervid, or bitter Properties, though they flow regularly, and in like Manner as all other perennial Springs do? Nor is Rain of any other Service, but to ſpoil them, as thoſe that ſtay long at the *Bath*, and other Places of that kind, can very plainly diſcern, and which generally puts a Period to thoſe ſalutary, and ſometimes pleaſant Meetings.

I MIGHT add a great many more Reaſons why Springs can by no Means owe their Original to Vapours, Rain, &c. but that I haſte to the next Chapter, which ſhews from whence Springs, with more Probability of Truth, do ariſe; in which the Arguments which have been omitted in this, will naturally fall in.

CHAP.

* Sommario de l'Indie occidentale, del S. Don Pierro Martyre, cap. 7. p. 6. Stamp. ven. L. an. 1565. ut vult D. Plot de Origine Fontium, p. 80.

† In Japonia fontem adeo fervidum prorumpere ſcribit Caronius, ut ignis vehementiſſimus licet fervore nulla aqua ad eum Gradum perduci poſſit; triplo etiam diutius retinere aquam, quam noſtra aqua Calefacta conſueverit. Varen. Geog. Lib. 1. cap. 17. Prop. 8.

‡ Cauſa & generatio thermarum eſt. Prop. 8. Admixtio ſulphurearum particularum dum aqua per Suterraneos meatos fertur ut teſtat idem Varennius, Lib. 1. Cap. 17. prop. 8. præd.

CHAP. III.

Of the Opinion of thoſe who, with more Probability, attribute the Original and Riſe of perennial Springs to ſubterraneous Cauſes, &c.

I Come now in this Chapter to give the moſt probable Account I can of the real Original and Riſe of Springs, and ſhall, with Dr. *Plot*, divide the various Kinds of them in the following Manner:

Firſt, SPRINGS, which are temporary, and do not flow continually, which are again divided into

Thoſe which flow regularly, yet are uncertain, as proceeding from Rains; or certain, though periodical, as flowing at ſome certain Seaſons, yet dry in others.

Or irregular, which are alſo thoſe that are annual, which flow ſomething every Year, though at uncertain Times of it; or ſeptennial or decennial, which flow or are deficient ſeptennially or decennially.

Secondly, SPRINGS, which are perennial, and flow without ceaſing, which may be again divided into

Thoſe which are limpid, pure, and unmix'd, which flow either Guttatim, or Drop by Drop, or precipitately.

Or thoſe which are mix'd, and abound either with Salt; of which ſome are warm, as is ſeen in Hot Baths.

Or with Pitch or Sulphur, and are cold, as in Salt Pits, or in other medicinal cold Waters.

Of all which I ſhall proceed to give as ſuccinct Account as I can.

The Original of the firſt of theſe is manifeſtly owing to Rain or Snow; and their Periodical Flowings generally proceed from great Snow or Rains, which fall at certain Seaſons of the Year on ſome large contiguous Plains, or hilly and mountanous Grounds; and to this Cauſe, in a great meaſure, may be aſcribed the fourth Sort of Springs, or perhaps

haps rather to the Experiment of the *Tantalus*, as deſcribed by Dr. *Deſaguliers*, *Philoſophical Tranſactions*, N°. 384. which will (in the next Chapter) be more fully handled. Thoſe which flow and fall off every ſeven or ten Years, are indeed more difficult to account for than any: But what I moſt chiefly aim at, is, the accounting for thoſe that are plac'd in the laſt Claſs, and which are perennial, and flow always in a regular uniform Manner, and produce thoſe large Rivers with which the World is ſo well water'd, leaving thoſe, of which hot and cold Baths are compos'd to Phyſicians, and others whoſe more proper Buſineſs it is, to expatiate on that Subject, having always in View that which many learned Authors have long ago believ'd, that thoſe Kind of Springs which are perennial, have their undoubted Origin from the Sea, and which paſſing through the Veins and Ducts of the Earth in a due and regular Motion, are by the continual Preſſure of the Atmoſphere, and the Gravitation and Impulſe of the Moon thereon, rais'd up to the Tops or Sides of the higheſt Hills, though exceeding the preciſe Laws of Hydroſtaticks.

An Fontes oriuntur ex Mare, has been a Theme which has long ſubſiſted in Schools, nor has it been yet, I think, ſufficiently confuted, carrying, in my humble Opinion, the greateſt Probability of Truth of any Hypotheſis whatſoever, and towards the Augmentation of which, perhaps, Rains, Snows, Miſts, Vapours, and other tumid Exhalations, may contribute ſomething; for were it not ſo, and that there was a watery Foundation below, that does ſtop and impede all thoſe Waters that fall from above, Water itſelf being of ſo ponderous a Nature, would (as *Marriotte* otherwiſe obſerves,) ſink down towards the Center (rather than break out of the Sides) of Hills; but when Waters, that come from above, meet with thoſe that ariſe from below, the Interception, or Claſhing of the one with the other, is the undoubted Cauſe that they break out with that Violence they do, on the Sides of Hills; and the Reaſon why ſome Hills abound with Springs more than others, ſeems to be on account of thoſe Vents or Paſſages of rocky Stone and Gravel, intermix'd with Sand or rubelly Clay, all which give way for the Springs that are below to aſcend, as they do the Waters above to deſcend for that Purpoſe; whilſt all large campaneous Countries, which have no ſuch Variety of Materials, through which the Springs can paſs, are either by a thick ſolid Body of Stone, Chalk, or Clay, ſo chain'd down, that they can't riſe from below, which Bed alſo keeps thoſe that are above from deſcending down, any other than to ſatisfy the Drought of the Earth, and the Herbage that grows thereon; ſo that

(to ſpeak in plain Terms) what by the one, or what by the other, there is no Water to be had, unleſs you dig through thoſe deep and dry Rocks to a very deep and low Situation, communicating, as may be reaſonably ſuppos'd, with Rivers, if not the Sea itſelf; the Salt and Brackiſhneſs whereof is loſt in its Percolation, through the Pores of the Earth.

THIS ſeems alſo to be the Opinion of ſome great Men, ſince *Cardan*, in his Treatiſe *de Subtilitate*, *Lib.* ii. *p.* 166. before mentioned, ſays, (to uſe his own Words,) *Putei Effoſſi quo magis à mari diſtant, eo minus ſunt Salſi*; and my Lord *Bacon* ſomewhere affirms the ſame; and that *Cæſar*, which is confirm'd alſo by *Hirt. Panſ.* in his *Comment. de Bello Alexandrino*, cap. 9. made Experiments of it when he was beſieg'd in *Alexandria*, and thereby ſav'd his Army, which was in Danger of periſhing; and that it was Sea-Water he likewiſe affirms, becauſe the Pits which he digg'd, roſe and fell as the Tide did, as do the Waters in or near the Sea-Port Towns of many Places of *England*, as is elſewhere obſerved.

OF this Kind alſo was a Spring or Rivulet ſomewhere in *Carnarvonſhire*, mentioned by *Camden*; another there is, as *Varennius*, in his *Geography*, *Lib.* I. *cap.* 17. *prop.* 17. witneſſes, which he calls *Marſaca vaſconum*, (the Tranſlation of which I cannot find in my Dictionary,) where the Tides of the *Garonne* flow upon a Level to *Bourdeaux*; a third alſo there is, which *Gaſſendus*, in his *Phyſicks*, *Sect* 3. *Memb. pr. Lib.* i. *cap.* 7. mentions, in a little Iſland near the Banks of the *Timavus*, a great River of the *Carni*; but theſe are nothing to compare with one in the Province of *Connaught* in *Ireland*, which, as (Dr. *Plot*, p. 102. of his *Tentamen*, &c. ſets down,) being on the Top of a high Mountain, exactly flows and reflows with the Sea-Tides, and yet is ſaid to produce ſweet Water. Like to this alſo is a Spring which they call *Lanzara*, amongſt the Mountains of the *Cabretti*, in *Spaniſh Gallia*, which, as *Varennius* ſays, *Lib.* I. *cap.* 17. *prop.* 17. *prædic.* flows and reflows in that Manner, tho' it is twenty Leagues Diſtance from the Sea. To which may be added, (one which is more remarkable than all the reſt,) which is the Mountain *Erminium* in *Luſitania*, or *Portugal*, which raiſes its Head, (as *Vaſconcellus*, *cap.* 5. of his Deſcription of that Kingdom has it,) like a Pyramid, and eſpecially in that Part, which the Inhabitants, for Diſtinction ſake, term *Montem comtari*, as I find it in *Plot*, p. 103. In the very Tip-top of which Hill, (to uſe the Words of *Vaſconcellus* himſelf,) "There ariſes a Lake, which has many "Paſſages in its Circuit, that with great Punctuality and Obſervance "follows the reciprocal Motion of the Tides in the Sea."

BUT

But we need not go ſo far to find out the Correſpondence there is between the Sea, Rivers, and ſubterraneous Wells and Ducts of Water, there being (beſides many other Places which might be named) ſeveral Wells at a little Village called *Spittle*, about ten Mile beyond *Lincoln*, in the Road to *Barton* and *Hull*, the Surfaces whereof riſe and ſink in the ſame Manner as the River *Trent* does, though it be near fifteen or twenty Miles off; and ſo remarkably true it is, that the late Lord *Caſtleton*, who had great Poſſeſſions on the Banks of the ſaid River, and liv'd ſeven or eight Miles, or more Diſtance than *Spittle*, never ſent any farther than that Place to know the State of the River, and whether or no his Cattle which were feeding at that great Diſtance, were in any Danger of being drowned by the Overflowings of it; from all which, with the induſtrious *Plot*, (p. 103. *prædic.*) it may be certainly pronounc'd, *That there is a certain Commerce or Correſpondence which paſſes between Springs and the Sea.*

The ingenious and learned Mr. *Ray*, (one of the greateſt Sticklers for the Derivation of Springs from Rain,) in his Treatiſe of the Diſſolution of the World by Fire, allows that there are thoſe ſubterraneous Paſſages, which *do, and muſt neceſſarily communicate with the Sea*, (Vid. p. 69. of that Treatiſe,) and inſtances that of the *Caſpian* and *Mediterranean* Seas, which receive into themſelves many and great Rivers, and yet have no viſible Outlets, nay, that the laſt receives alſo abundance of Waters from the great Ocean, running in at the *Streights* of *Gibraltar*: And therefore, by ſubterraneous Paſſages, muſt needs diſcharge theirs into the great Abyſs or Fountain of Waters under them; and then, (but by which Way he does not tell us,) they break out into the Ocean again; and his main Objection (as indeed it is the chief of all thoſe who are againſt the Hypotheſis I am endeavouring to explain) is, how it can poſſibly be, ſince Water is well known to keep to its Level, and cannot aſcend to any great Height above the common Center, that is, than the Superficies of the Sea is, much leſs, ſays he, is it able to force its Way, remove ſuch Obſtacles, and break open ſuch Paſſages as it does.

To which I anſwer, that this ingenious Author does not ſeem well acquainted with the ſucceſſive Laws of Preſſure or Pulſion, or rather how Liquors aſcend in capillary Tubes, all which I ſhall endeavour to explain in the next Chapter. The ſpecifick Gravity of the Earth being ſo much greater than that of Water, is, I humbly conceive, a ſufficient Reaſon to induce any one to believe, that this Aſcent is not only probable, but abſolutely reaſonable and neceſſary, nor does

the Account which Sir *Thomas Willoughby*, in his Coal-Works, gives, invalidate, but rather makes for that which I have been all along giving of Springs, which is as follows: " If the Springs, " (fays this Noble Gentleman,) lie before you come to the Coals, " they carry the Water away," *i. e.* (as I apprehend he means,) *if there are conftant Springs which break through the Chafms of the Coal from below, they ftop the Rain-Waters, and carries them all away:* But if there be no afcending Springs, it falls by the Laws of Gravity into the Works in greater or lefs Quantities, according as the Rains fall. But this ingenious Author is of another Mind from me, and fays, that this is a farther Proof to him, that Springs are fed by Rain-Water. If he means Land-Springs or Top-Springs, he is certainly in the Right; but if he means thofe which are perennial, and flow conftantly, he is as certainly in the Wrong, as has been demonftrated in the foregoing Chapter, in the Example of the *Upminfter* Spring, the Account whereof was taken by Mr. *Deerham*, who has made Rain his favourite Study, and alfo that of *Chelmsford* in *Effex*, which was lately taken by my felf, befides many others, which might be produc'd.

As to what Mr. *Ray* fays of the extraordinary dry Summers which happen'd in 1654, 55, and 56. when our Climate was drier than it had ever been known in any Story, and which had dried up moft of thofe Springs which had never been (in the Memory of the eldeft Man living) known to be dry before, I anfwer, that at that Time, fure enough, alfo the Water was low, and the Tides never arofe fo high in the Sea, as they us'd to do, and which is the undoubted Occafion why one of the *Chelmsford* Springs (as I have already obferv'd) rarely breaks out, at leaft, affords much Water in Summer. Nor is it to be doubted, but that the Account the Laborious *Heylin* gives of the great Drought, which was in the Days of *Conftantine* the Great, which lafted thirty fix Years, by which all the Springs and Torrents, or Brooks, were dried up, fo that the Inhabitants were forc'd to forfake the Ifland, and feek new Habitations, for Want of frefh Water, proceeded from the above mentioned Caufe, *i. e.* the Lownefs of the Surface of the Sea; nor can it have a little Weight, when we confider, that though there fhould be fmall Eruptions of Water out of thofe perennial Springs, that the Drynefs of the Ground is fuch, that they will immediately fup it up; nor muft it be difown'd, that in all large Rivers, (fuch as our ingenious Author fays were dry in 1654.) there are great Additions in all Gluts of Rain, by which they are much increas'd, (at leaft, as to diftant Appearance;) but this is far from making perennial Springs.

But to return: It ought not to be omitted, as more fully confirming the Opinion aforegoing, of the Communication of the Sea with Land-Waters, that there are in Being in many Places, unpleaſant Lakes which have no apparent Communication with the Sea, yet nevertheleſs abounds with Sea Fiſh, particularly one in the Valley of *Cajova*, in the Province of *Bayone* in *Spain*, called *Hagugabon*, which as *Peter Martyr* relates, (in his Treatiſe, *De Anglerii orbe novo*, *Dec.* III. *cap.* 8.) is thirty Miles in Length, and twelve in Breadth; and receives twenty four Rivers of freſh Water which fall from the Hills into it, yet by the Force of the Salt Water it ſometimes ebbs and flows in ſuch a Manner, and is ſo brackiſh and unpleaſant, as to nouriſh what they call there the *Canes Carchinas*, and other Sea-Fiſhes; and as it vomits out ſome Waters, ſo it ſups up others, and that with ſo great a Violence, that even the Fiſhermen and their Boats are ſometimes ſwallowed up in it. And he adds, that there is another in the ſome Province in every Reſpect like the former, but that it is leſs.

Varennius, (*Lib.* 1. *cap.* 15 *prop.* 7.) in like Manner reports, that he found two large Lakes in the Iſland of *Cuba* in *America*, which was ſalt, and produced Sea-Fiſh, although it received at the ſame Time ſeveral freſh Water Rivers into it ſelf. Another of the ſame Kind, adds *Varennius*, is in *Peru*, another in *Menuthia*; and that the Lake *Aſphaltites* in *Judea*, though it draws the pure Streams of *Jordan*, yet its Nature is ſo changed by the ſuppoſed Correſpondence it has with the Sea, and is ſo heavy, that nothing will ſink it, and is by ſome, for that Reaſon, called the *Dead Sea.*

To all which may be added that which is called the *Caſpian* Sea before mentioned, though it correſpond with other Rivers of no common Magnitude, and receives all the Water of the *Volga* into it ſelf, which produces ſuch Quantities every Year, as would ſuffice for the Supply of the whole World, (if I may uſe Doctor *Plott's* Words,) yet it abounds always with ſalt Water, and produces Sea-Fiſh; nor does it ebb and flow leſs than the *Mediterranean* Sea it ſelf. Theſe and many more Examples which might be produced, are ſufficient for our Enquiry, how it comes that thoſe Lakes contract that Unpleaſantneſs; and by what Method it can be that Sea Fiſh are carried thereinto; and how, laſtly, it is that thoſe immenſe Quantities of Water, ſuch as are in the *Caſpian* and *Mediterranean* Sea, which never tranſgreſs their Bounds, ſhould be ſalt or brackiſh, unleſs it be granted that there are Paſſages, by which thoſe Lakes hold Commerce or Correſpondence with the Sea, and the Sea with them.

To

To omit much more which the induſtrious and learned *Plott* has produced to prove the ſubterraneous Correſpondence there is between the Sea and Springs and Lakes, it remains next for us to give a ſhort Account of ſome Springs Heads which are on high Hills, very far diſtant from the Sea, and to enquire by what Means Water riſes to the Top thereof, Facts which have met with great Oppoſition from thoſe who have declared in Favour of Rains, Snows, and other Hypotheſes, and Doubts in many learned Men, whoſe Enquiry into this Part of Nature have been conſiderable, the Elevation of Springs to ſuch great Height, much exceeding the preciſe Laws of Hydroſtaticks, *&c.* All which I ſhall treat of in their particular Order.

The firſt is, that it is certain there are many very high Hills, very diſtant from the Sea, which have no ſuperior Tract of Land to ſupply them with, but muſt neceſſarily riſe through its Mole or Body: Such is the Head of the River *Marſyæ*, which *Quintus Curtius* teſtifies, (*Hiſtoriarum Lib.* III. *in initio*,) riſes from the Tip-top of a very high Mountain. Another there is, as *Cardan* relates, which falls from the Summit of prodigious high Rocks in the Iſland of *Maia*, upon the Borders of *Fife* in *Scotland*, though the ſame is not above two Miles in Circumference: As alſo another in the Iſland of *Bonnica*, not far from *Hiſpaniola*; for which ſee *Cardan de Subtilitate*, *Lib.* II. *page* 92. and *De rerum varietate*, *Lib.* I. *cap.* 6. *in initio.* And Sir *Robert Sibbald*, who wrote an Acconnt of *Scotland*, in his *Prodrom. Pars prima*, *Lib.* I. *cap.* 9. tells us, that there was alſo a perpetual Fountain on the very high Top of the Mountain *Lominius*, in the Iſland of *Hoia* of the *Orcades*, on which there were three other Hills, obſerved for their Height, are admired by all Navigators at Sea, though far diſtant from it, and which appear like ſo many Piers or Landmarks: That there is in the Tops of one of the three, that riſes out of the very Heart or Foundation of it, a very ſtrong Spring. And the ſame I have been told is to be found on a Hill called *Pennichy*, or *Bend-up-high*, near *Aberdeen* in that Country, which runs continually, though there is no contiguous ſupereminent Plain that lies above it, or indeed near equal to it. The like I have alſo ſeen my ſelf on the Top of a high Hill near *Marlborough* in *Wiltſhire*, called *Martinſhall*, or *Martincell* Hill; where, though the Ducts and Veins of the Earth are not large enough to emit a conſtant Stream, but to break out Guttatim, or Drop by Drop, as ſome perennial Fountains do, yet it has not been known to be dry in the Memory of any Body now living: And by its Clearneſs it is very likely to have its Origin through ſome ſmall Veins which riſe through the Hill, though its great Height and Diſtance from the Sea is alſo ſuch, that

that it can't ſend forth any large Quantities by any of the Laws of Hydroſtaticks, or other Means.

To this Account of the Procedure of Springs out of high Hills, (which have none that are ſupereminent to them,) may be added the Account that an ingenious Surgeon, who uſed the *Weſt Indies*, gave Mr. *James Young* of *Plymouth*, as may be ſeen in *Hook de Potentiâ Reſtitutivâ*, printed by *John Martyn*, Printer to the Royal Society, 1678. who aſſured him that there was a Spring which ſent forth large Streams of Water, at which Ships were frequently furniſhed; and that there, as well as in the Iſland of *Mayo*, it rained but once a Year; that the Iſland from its Figure was called the *Rotunda*, and having no Ground which lay above it, could not by any Means produce a Quantity of Rain-Water ſufficient to maintain that great Flux which was there ſo viſible, even though it was to rain without ceaſing. That in the Iſland of *Mayo*, of which Mention was made in the laſt, and which the aforeſaid Mr. *James Young* alſo mentions, the Springs (as may be ſeen in the Draught he has given) are ſeen breaking out of a round Hill, at the upper End of that Iſland, higher than which there is no Ground, neither had it rained there for a conſiderable Time, though the Spring ran conſtantly and without Interruption quite through the Middle thereof. The ſame alſo may be obſerved in the *Inſula Vectis*, or Iſle of *Wight*, at a Place called *Appledore Comb*, the Seat of Sir *Robert Worſley*, where, though there is Land much above it, yet the Rains run off it with that Precipitation, that they never ſcarce enter the Herbadge, at leaſt, ſo as to ſink down, and make Springs.

To proceed with the learned *Plott*, it is worthy Remark what the moſt honoured Mr. *Boyle* obſerved on the maritime Coaſts of *Waterford* in *Ireland*: He ſaw a Mountain, from the ſuperior Clift of which ran a River of a moderate Amplitude, which had broke out there but juſt two or three Years before (without any manifeſt Cauſe) from a Moraſs which was at the higheſt Verticity of it; and from thence runs a great Ways, and affords a daily conſtant Stream to its Inhabitants; which if it had had its Original from Rains or Snows, he ſuppoſed would have ſhewed it ſelf many Ages before: But from ſo ſudden an Eruption it was moſt reaſonable to believe, that it had but juſt then found (I may add forced) its Way through the Chaſms of the Ground beneath, and being (if I may ſo expreſs it) glad of its Liberty, flow'd on an uniform uninterrupted Succeſſion. Moreover, *Scaliger*, (in his Treatiſe *De Subtilitate*, *Lib.* XV. *Exercit.* 46.) teſtifies, that there was near his *Villa* a large Spring, which came from the extream Top of a Mountain, though the Ground in no Part of the

the Neighbourhood afforded the ſame. He adds alſo, that there was a boiling Lake, which abounded with hot Springs, in a Plain over againſt the Top of the Mountain *Cinis*, in the *Alps*, to which ſpacious Plain there was no higher Ground which could adminiſter Water to it, and ſo could not proceed from Rain.

A SECOND Thing I have to ſpeak to in the Courſe of this Chapter, is to anſwer an Argument which the Diſſenters to the Hypotheſis (I am now endeavouring to explain) produce, who would neceſſarily have the Original of Springs owing to Rain; becauſe, ſay they, (though by Way of Aſſertion without real Proof,) in all large Plains there are none any where found but what proceed from contiguous Hills. This has, in ſome Meaſure, been anſwered already, but will be more fully ſo in the Thread of this Account of Springs, wherein this Aſſertion will be prov'd to have no Foundation of Truth in it; ſiince the ingenious *Boetius*, in his Natural Hiſtory of *Ireland*, *cap.* 7. *ſec.* 1. aſſures us, that there were many Places in that Kingdom from which large Springs and Rivers had their Riſe, when at the ſame Time they were rarely to be found in Hills contiguous, or far off from them in that Part of the Country.

THE ſame Thing is alſo obſervable in the Riſe of the Rivers *Rea* and *Iſis*, which break out near the Town of *Fritwell* in the County of *Oxon*, which draw their Original from ſo humble a Plain, that there is ſcarce any Declivity ſufficient for their Current, much leſs Supply. And this likewiſe is the Opinion of that curious Obſerver of Meteorology, the Reverend Mr. *Deerham*, in his *Phyſico Theology*, *page* 50. before recited.

BUT we need not rely altogether on the Obſervations made at home, where Springs ariſe in large Plains which have no Hills contiguous to them: The River *Pyramus* in *Cappadocia*, which although *Strabo* calls it πλωτὸν, *i. e.* a navigable River, yet he relates that it breaks out of a Middle of a plain Field, as may be ſeen in his Geography, *Lib.* XII. page 536. of the *Paris* Edition, *Anno* 1620. Beſides the large River *Tanais* proceeds from a large open Field in *Muſcovy*, as *Agricola*, in his Treatiſe, *De Natura eorum quæ effluunt ex Terrâ*, *Lib.* III. *in initio*, deſcribes.

To this may be joined what *Cluverius*, *cap.* 6. of his *Vindelicia & Niric.* writes of the *Danube*, the greateſt River of *Europe*, whoſe Head, (ſays our Author,) though it flows perennially, and is twenty ſix Foot long, and eighteen Foot wide, yet it riſes in an open plain Field in the Village of *Eſchinger*, or *Donaſching*, or as, *Jornandes* will have it, in the Fields of *Alemanicis*, and not as *Herodotus*,

tus, *Tacitus*, *Plinius*, and *Marcellinus*, have delivered it down, from the Foot of a Hill, or large Mountain.

To all this may be added, what I have read in an Account of *Switzerland*, wrote ſome few Years ago, as 'tis ſaid, either by Mr. *Manning* or Mr. *Stanyan*, Ambaſſadors from the Crown of *Great Britain* to thoſe States, that there was in that Country a Tract of Land, whether Hills, or no, I don't remember, which ſends forth four Rivers, which take their Courſe four ſeveral Ways, not unlike the Production of thoſe four famous Rivers of *Piſon*, *Gihon*, *Hiddekel*, and *Euphrates*, ſaid in Holy Writ, to have iſſued out of *Paradice* itſelf; a plain Inſtance that neither Rain or Vapours can be the Cauſe of thoſe perennial and uninterrupted Springs with which the greateſt Part of the World is water'd, but that they come from a much more deep and latent Cauſe.

There is a third Caſe, which ought to be ſpoke to more largely than I have as yet done; and that is, That Water paſſing with more Difficulty through the cloſe clayey Veins of the Earth, few Fountains are ever obſerv'd there; when at the ſame Time they are never wanting in arenacious and ſtony Ground, through which the Water eaſily percolates; but that this does not make for the Suppoſition of Rain and Vapours being the Origin of Springs, but rather much againſt it, is already ſet down: And to confirm what has been offer'd on this Head, the ingenious Sir *James Young*, before mentioned, as we have it in *Hooke*'s Lectures, *De Potentia reſtitut.* p. 39. and as is alſo before hinted at in the Weſt Country, there is, as Dr. *Plott* obſerves, a large Tract of Land in the County of *Kent*, which is about ſeventeen Miles in Length, and five in Width, in which there is not one Spring to be found; and the ſame may be ſaid, I dare ſay, in Thouſands of other Places.

The laſt Thing to be examin'd in this Narrative of Springs, is a Deficiency, that upon Deliberation appears to be in the Produce of Rain, as related by an Anonymous *French* Author, who is the ſame which, in all Appearance, is hinted at by *Marriotte*, but more plainly by Dr. *Plott*, in p. 69, &c. of his Treatiſe *of Springs*, where, according to that Author's Calculation, at nineteen Inches deep, which is four Inches more than *Marriotte* ſuppoſes, there does not (at *Willowbridge*, where this Obſervation was made) fall Rain ſufficient for the Supply of the Springs in that Space, by 4811854 Hogſheads in a Year; to which, ſays the learned Doctor, may be added, that a vaſt Quantity of that Water which ariſes from Rain, Snows, &c. running, or to run out of Rivers into the Sea, are taken up in the Nouriſhment of Plants, and for the filling of the Pores of the Earth; which immenſe Quantity

tity the learned *Liſter* and *Willis* have demonſtrated, (as is ſeen in the Natural Hiſtory of *Oxfordſhire*, *Cap.* ix. *Sect.* 95. and in Mr. *Liſter*'s Treatiſe, *De Aquis Med. Angl. Exercit. Cap.* xi) that the major Part, if not all the Rain and Snows which fall, are again exhal'd up in Vapours, for the Creation of more Materials of that Kind, maintaining the ſame Circulation, or Aſcent and Deſcent, in the open Air, as is beneath in the Bowels of the Earth. Beſides, how comes it to paſs that Springs ſhould maintain their conſtant Current in ſcorching Deſarts, where they have ſeldom any Rains, (as in thoſe of *Arabia*, &c.) and in dry or cold Earths, or Fens; as alſo Woods and Groves, which when clear'd away, takes off that ſtagnate Air which is the Occaſion of that Moiſture and Dampneſs, with which thoſe Countries were once rendered obnoxious, and which conſequently (according to thoſe Hypotheſes which maintain Rains) ſhould decreaſe their Springs, yet they ſtill maintain their Current, and change the very Temperature of the Element; and that which was before cold and moiſt, is thereby forthwith made hotter, and more moderate, and ſo not capable of that Fund of Humid Air, Vapour, Rain, and which, according to them, is the Cauſe of Springs. So it is, that *Pliny*, in his *Natural Hiſtory*, *Lib.* xvii. *Cap.* 4. notes of the Ground adjoining to the City of *Philippis*, which being clear'd away, and turn'd into Tillage, it grew dry, and chang'd the Genius of the ambient Air, *&c.* ſo that it might (from the Limpidity of its Streams, which flow'd continually, and without Interruption) be taken for the Habitation or Ambit of Heaven itſelf.

The ſame alſo has happened in the Colonies belonging to the *Britiſh* Crown in *Barbadoes* and *Jamaica*, where the Woods being clear'd, and the Country expos'd to the Sun, there has fallen a leſs Quantity of Rain than was us'd to do, as may be ſeen in *Philoſophical Tranſactions*, Numb. XXVII. p. 49. How much of that Kind has happened in the Bogs of *Ireland*, and in the Fens of *Lincoln*, and *Cambridgeſhire*, need not be expatiated on; and thus from the Conſideration that Springs have ſubſiſted for ſeveral Years, where there has been a Decreaſe of Rain, and has not increas'd where there has happened a great deal; that there are many Springs in the World, which riſe and fall as the Sea does; that there are many Lakes on Inland Grounds, which have no viſible Communication with the Sea, yet produce Salt-Water; to which may be added, what I have omitted hitherto, that there are abundance of Shells, *&c.* which are found by digging in the Bowels of the Earth, which belong to the Sea: Theſe Reaſons, I ſay, confirm'd by Examples, ought abundantly to ſatisfy

ſatisfy the curious Reader, that there are ſuch Hollows and ſubterraneous Ducts in the Bowels of the Earth, through which Springs draw their Original out of the Sea; and that they are not owing to any other Cauſe.

The chief Thing which ſeems now to remain, is to give a more particular Account of the Methods by which Water is rais'd to the Tops of Hills.

Pliny ſuppoſes it to be thrown up by the Impulſe of the Air, which is included in the Caverns of thoſe Rocks and Mountains, as it were, through a Syphon.

Plutarch tells us, that from hence it is that Water iſſues out of new-broke Ground which is moiſt, juſt as the Blood does out of a Wound, or the Milk from the Paps of a Nurſe; which, ſays an ingenious Author, is worthy of our Contemplation; and by this Means it is, that the Blood in all Scarifications is carried up, or rather extracted from the inner Maſs, *viz.* according to the Laws of Attraction, or rather Pulſion, to which all Cauſes, both phyſical and mechanical, are now reduc'd.

Rohault, in his Phyſicks, (*Par.* iii. *cap.* 10) ſuppoſes, with others, that Water has its Origin from the Sea; and that it is rais'd to the Tops of Mountains by the latent Heat of ſubterraneous Fires, which (whether central or deſpers'd) diſſolves that Water into Vapour; and by this means it is (ſays he) that Water, which is in Places at a great Diſtance from the Sea, is drove by its own proper Weight and natural Fluidity, and ſo lifted up to the higheſt Hills; for when thoſe Vapours can't move Sideways, and extend themſelves which Way they pleaſe, becauſe of others which are every where aſcending, and endeavouring to expand themſelves at the ſame Time, it is (ſays he) neceſſary that they ſhould be carried upwards to the Tops of Mountains, and moſt certainly to turn into Air and Vapour, being future Materials for Rain, Snow, and Hail.

This being granted, it is eaſily underſtood, ſays he, that thoſe Vapours, being brought to the ſuperior Part of the Ground, and detain'd amongſt the cold Particles which inhabit there, loſe great Part of their Motion, and ſo can't aſcend any farther, but are then turn'd into ſmall Drops of Water, which by their Gravity flow out again; and by the Acceſſion of other ſmall Drops, added to thoſe other which were before form'd, increaſe into a ſmall Vein of Water, and flowing from thence, run into other Veins like it ſelf, and, at laſt, into one large Vein or Artery of Water, breaking from thence, through ſome Paſſage or other, out of the Hill or Mountain, and then becomes a Spring

 or

or Fountain of Water, which fupplies all Refervoirs, Bafins, Pits, Ponds, &c. that lie in its Way.

THIS, indeed, feems to be a fine Way of adjufting this great Affair; but, in anfwer to it, it muft be faid that the Exiftence of fubterraneous Fires, if any fuch there are, ferve for other Purpofes than what this learned Author fuppofes they do, it being doubtful, if not mathematically and morally impoffible, as *Marriotte* has in general obferved, that Air or Vapour, whether lodged in the Caverns of the Earth, or detatched from Fountains below, fhould adminifter a Supply of Water equal to what the leaft of the Rivers, we have before fpoken of, can emit. Befides, it is not eafy to give an Account how Vapours fo diftill'd, and in fuch a State of Rarefaction, fhould afcend through fuch Bodies (fuppofe them to be of Rock, Gravel, or Sand) as Springs proceed from.

As difficult (if not much more) is it to account how two fuch fudden Tranfmutations of Elements fhould immediately, and in fo regular a Courfe, fucceed each other, and be effected fo perfectly, and in fo little a Time; and how capacious and extenfive thofe Receptacles muft be, wherein that great Work is performed, may be gueft at by what follows.

THE learned and moft accurate *Robert Boyle*, fomewhere fays, That an Inch of Water rarified into Vapour (as it muft be in Cafe of fubterraneous Fires) is divided into 13300 Millions; and that one Drop of Water only is divifible into twenty-fix Millions of Parts. This Rarification, and confequently Expanfion, muft, I fay, take up fo much Room for fuch a Change, that one fhould be very hard put to it to find where it is fituated; and how fo great a Work fhould be fo juftly effected as to keep the Streams of a River, or even a fmall Spring, in a conftant Current and Supply.

IF there are any Things then as fubterraneous Fires, (which by the Steam that arifes in Cellars, and from hot Baths that reek fo, there is fome Indication there is,) the Ufe of them feems to be more probably this, *viz.* That it may rarify the Air in thofe Paffages the better, and caufe the Water by the Impulfe of exterior Air, and other Fluids, to afcend the freer, as Heat does in the Pipes of a Fire Engine, where it is feen to mount to the greateft Height; but Water rarified into Vapour, would rather adhere and ftick clofe to thofe Particles of Stone and earthy Matter through which they are to pafs, than ever to afcend through them, which, in my humble Opinion, is a Confideration of no fmall Moment.

THE

THE next Thing to be taken in Courſe, is to give the beſt Account I can, how it is that Water may be raiſed to ſo great a Height.

AND, 1ſt, That Water may be made to aſcend above its proper Level by its own Inclination; 2dly, according to *Plott*, by the Help of Fire; 3dly, by Filtration; 4thly, by Attraction; and, 5thly, by the unequal Altitude of the Sea, which is proved by many Examples; 6thly, by the Help of the Diſtance of the Center of Gravity from the Center of Magnitude; and, laſtly, by the additional Weight of the Atmoſphere, Gravitation of the Moon in all high Tides, by the Help of Storms, Tempeſts, *&c.*

Firſt of all, Tho' it be true that Water, according to the preciſe Laws of Hydroſtaticks, will not riſe higher than its Level, (if ſo high,) yet the Movement of aſcending and deſcending Water in a Mountain is of another kind, as is ſeen in ſalt Sea-Water, which is more ponderous; and that of the Fountain, which is ſweet and clear, and conſequently lighter: Moreover, when the firſt preſſes downwards, and the later aſcends in round Tubes, which ſtill decreaſe till they are ſo diminiſh'd, as to turn into the fineſt Streams imaginable, ſuch as Air, *&c.* and as Salt-Water is alſo always preſſed by the immenſe Weight of Air; which ſpreading itſelf wide on its Superficies, I can't ſee, (ſays my Induſtrious Author,) when all theſe Things are duly weighed, why it ſhould not be believed, that the ſame Water ſhould not be made to aſcend higher than its firſt Level, even ſo long till it iſſues forth out of the Sides of Hills, in like Manner as Quickſilver is raiſed by the Air's Preſſure on that ſubjected ſtagnated Maſs, eſpecially when it is not depreſs'd by any ſuperincumbent Fluid, as is the Caſe in the open Air.

BUT, which is more to the Purpoſe: Another Reaſon why Freſh-Water, when ſtripp'd of its heterogeneous Parts, and made fine and ſupple, ſhould aſcend with Eaſe through the capillary Tubes or Fiſſures of the Earth by the collateral Preſſure of complicated exterior Powers, which are always agitating and gravitating thereon, is its Fluidity; to which may be added, (what is juſt now hinted at,) that continual innate Heat, which, according to *Carteſius*, in his *Princip. Philoſoph. Par.* 4. *Sec.* 64. and the Reverend Dr. *Shillingfleet*, then Dean of *St. Paul's*, in his *Origin. Sacer. Lib.* iii. *Cap.* 4. is always labouring in the Bowels of the Earth; a Proceſs not diſagreeable to what the ingenious Mr. *Hawkſbee*, (in his *Phyſico-Mechanical Experiments*, *p.* 144. *Exper.* 5. *&c.*) deſcribes, when he gives an Account of the Aſcent of Waters through a Tube filled with Aſhes, (in the open Air, and in *Vacuo*,) there being naturally an innate Heat, which cauſes that Siccity, Drought, or Thirſt, as is viſible in Lime, and other calcined Bodies, which abſorbs all Moiſture to itſelf, and which, as this ingenious Gentle-

man has very clearly demonftrated, is the Caufe by which Water will rife through its Interftices, even beyond, and, I may fay, in outward Appearance, without that adventitious Affiftance which is deduced from the percife Laws of Hydroftacy, or the Equipondium or Balance of exterior Fluids, collaturally gravitating thereupon.

He took a Glafs Tube thirty-two Inches long, tied a fine Piece of Cloth to the End, and filled it with Afhes fifted very fine, and as he put them into the Tube, ramm'd them down as clofe as pof-fible. When the Tube was filled, a thin Bladder (which was freed from all included Air) was tied to the other End of the Tube, to receive the Air which fhould afcend through the Afhes as the Water rofe: This done, the Tube was immerg'd into Water, and it was found that in the Space of fixteen Minutes, it had rofe 1 Inch $\frac{3}{4}$; at the End of twenty-four Hours, (for the higher it went, the flower it rofe,) it had rifen only fixteen Inches, the Bladder at the Top being then near half filled with Air. An Accident then happened which did prevent any more Obfervations on the extending the Bladder; but the Water ftill rofe higher, though flower than at firft; and in twenty-four Hours more, it rofe fix Inches; again in twenty-four Hours, it rofe four Inches and an half more; the fucceeding twenty-four Hours, two Inches higher ftill; and being arrived within half an Inch of the Top of the Tube, that Space was filled in about ten Hours more.

Many are the curious Obfervations that this ingenious Gentleman has made on this Experiment; but whatever was the Caufe of the Afcent of that Water, it acted uniformly, fince the Water in all its Parts was equally influenced by it; and had the Tube of Afhes been higher, the Water would undoubtedly have been raifed through it. It may, indeed, be faid that the Water in this Experiment was raifed not higher than Mercury (which is of a more ponderous Nature than Water is) rifes; but then it muft be confidered that the Rifing of the Water in Afhes was through a Plenum; and the general Rife of all Water in open Air, through a real Vacuum, at leaft, a Vacuum differninatum, (as the Learned term it,) nor will Water rife to thirty-two Foot high, fo often mentioned, till the Air is fucked out by a Syringe-Pump, or fome other Inftrument; fo that though this Rife of Water, may feem to owe its Motion to the received percife Laws of Hydroftacy; yet it is plain it did not, becaufe the Experiment did not fucceed better in Vacuo than in the open Air, though in a * Medium

* *The Afcent of Water through Afhes in Vacuo is demonftrated in* Exper. 6. Page 150. *of the ingenious Gentleman beforementioned, who fays he took a Tube about ten Inches in Length which*

dium it did: On which Account it is pretty plain, that it had its Riſe from the innate Heat, which laboured therein; which by its Colliſion againſt the more volatile fluid Flame, forced out the Air which was in the Aſhes, in order to give Room for itſelf; and that without the adventitious Aſſiſtance, or Equilibrum of exterior Air; which is what I was in this Place to reaſon upon.

Another Method by which Water is raiſed in ſmall Tubes, is *Filtration.* Now this Filtration is ſo well explained by the Ingenious Mr. *Hawksbee*, *Page* 28. of the aforementioned Treatiſe, that I ſhall make uſe of his own Words. "The Reaſon (ſays he) "of raiſing the Water in a Filtre, will be manifeſt to him who takes Notice that a Filtre is conſtituted of a great Number of ſmall long "Bodies (the Interſpaces of which may be called Capillary Tubes:) "Theſe Bodies lie ſo cloſe together, that the Air in its getting in "between, doth loſe of the Preſſure which it has againſt the Fluid "which is without them; by which Means the Water or Liquor not "finding ſo ſtrong a Reſiſtance between, as is able to counterbalance the Preſſure on the Surface which is without, is raiſed "upwards till it meets with ſuch a Preſſure as is able to hinder "it."

As to the Riſing of Oil, melted Wax, Tallow, Spirit of Wine, *&c.* in the Week of a Candle or Lamp, it is evident, that it differs nothing from the former, ſave in this, that in a Filtre the Liquor runs away by another Part, and in the Week the Liquor is diſperſed and carried away by the Flame.

And as for the Riſing of Water in a Spunge, a Loaf of Bread, Cotton, or any ſuch Subſtance, above the Superficies of the ſubjacent Liquor, (which the Reverend and Learned Mr. *Deerham*, in his Notes on his *Phyſico-Theology*, page 50. has hinted at,) what has been ſaid of the Filtre, if duly conſidered, will eaſily ſuggeſt the Reaſon of it: For this voluntary Aſcent, if I may ſo call it, (ſays the learned *Hooke*, Page 29. *Lib. prædic.*) it is, conſidering that all thoſe Bodies abound with ſmall Holes or Pores, that Water-Riſes being all of them

---

with Aſhes, (as before,) and placed it in a Reſervoir, out of which the Air was exhauſted, ſuffering it to continue in that State for ſome Time, to give Liberty for the Air which was in the Aſhes to get away, then plunging the lower End of the Tube under Water, it was found (as expected) that the Water roſe much faſter in the rarified Medium, than in open Air. *And this points out the Reaſon why the Water in the former Experiment roſe faſter at firſt, than when it had got up nearer towards the Top,* viz. *its being by its nearer Approach towards the Surface more ſenſible of the Reſiſtance of the ſuperincumbent Air; and this may be the Reaſon alſo why Springs don't always break out of the Tip-tops, but rather on the Sides of Hills.*

them no unlikely Demonſtrations of this Riſe through the Veins and Pores of the Earth, as the Sap does through the Trunk of a Tree; eſpecially if to it be added the unequal Altitude of the Sea, which will be proved from many Examples, when I have ſet down what the learned *Hooke* has ſuggeſted on this Head, namely, *That the unequal Height of the Surfaces of Water within, proceeds from the greater Preſſure of other Fluids which are without*, that is, from their being of a more ponderous Nature, as Salt-Water is more ponderous than Freſh; and by that Means, even by the known Laws of Hydroſtaticks, will raiſe the ſaid Freſh Water higher than its own Surface, provided the Reſiſtance of Air (which we have proved to be much leſſened in this Caſe) be not too great.

This different Aſcent of Liquors in Tubes of different Sizes, is viſibly expreſſed in the Veſſel G, Fig. III. Tab. ſeq. where the Tube C may repreſent Mercury, the Tube B another Liquid near of equal Weight to it, and the Tube A Vinegar, Fair Water, or any more ſubtil and thin Fluid, which are raiſed up to different Heights at E, D by the Gravitation of the Mercury in F.

From this it is that Doctor *Hooke* has drawn two Propoſitions; the firſt of which is, *That the unequal Preſſure of incumbent Air* (or I add, any other Fluid) *will cauſe an unequal Height in the Waters Surfaces*, which proceed from thence.

And the Second is, *That there is in this Experiment ſuch an unequal Preſſure.*

Let there be contrived ſuch a Veſſel, in which you can either increaſe or diminiſh the Preſſure of the Air upon this or that Part of the Surface of the Water, the Equality of thoſe Parts will be immediately loſt; and that Part of the Superficies, which ſuſtains the greater Preſſure, will be inferior to that which undergoes the leſs. A Veſſel fit for this Purpoſe, will be an inverted Glaſs Scyphon, ſuch a one as is deſcribed in Figure IV. Tab. ſeq. For if you put Water enough to fill it as high as A, B, and gently blow in at D, you ſhall depreſs the Superficies B, and thereby raiſe the oppoſite Superficies A to a conſiderable Height, and by gently ſucking, you may produce the quite contrary Effects.

Next, that there is ſuch an unequal Preſſure, I ſhall prove from this, That there is a much greater Incongruity of Air to Glaſs, and ſome other Bodies, than there is of Water to the ſame: But this particular Enquiry of Doctor *Hooke* is too long to be inſerted in this Place; which makes me haſten to that which is of more Uſe in the Treatiſe I am upon, and which was one of the chief Corollaries drawn by that great Man, (*viz.*) Whether from the ſeveral Properties with which

Water and other Fluids were endowed with, (which are by him reduced to the general Laws of Motion and Reſt,) the Riſing and Ebullition of the Water out of Springs and Fountains, (which are generally eſteemed to lie much higher than the Superficies of the Sea, from whence it ſeemed to be derived,) may not be explained by the Riſing of Water in a ſmaller Pipe: For the Sea-Water being ſtrained through the Pores or Crannies of the Earth, is, as it were, included in little Pipes, where the Preſſure of the Air has not ſo great a Power to reſiſt its firſt Riſing: But examining this Way, ſays my learned Author, and finding in it ſeveral Difficulties almoſt unmovable, I thought upon a Way that would much more naturally and conceivably explain it.

I Took a Tube Glaſs of the Form of that deſcribed in the IVth Figure, Tab. ſeq. and chuſing two heterogenous Fluids, ſuch as Water and Oil, I poured in as much Water as filled up the Pipes as high as A, B; then putting in ſome Oil into the Tube A, C, I depreſſed the Superficies A of the Water to E, and B I raiſed to G, which was not ſo high perpendicularly as the Superficies of the Oil F, by the Space F I; wherefore the Proportion of the Gravity of thoſe two Liquors was as G, H, to F, E.

This Experiment was alſo tried with ſeveral other Liquors, and particularly with Freſh Water and Salt, (which was made by diſſolving Salt in warm Water;) which two, though they are nothing heterogenous or diſſimilar one from another, yet before they could perfectly mix with one another, I made Trial of the Experiment: Nay, letting the Tube, wherein I tried the Experiment ſtand for many Days, I obſerved them not to mix; but the Superficies of the Freſh, was rather more than leſs elevated above the Salt-Water. Now the Proportion of the Gravity of Sea-Water, to that of the River, (according to *Stevinus* and *Varrennius*, and which has been ſince found by other very curious Experiments, is as 46 to 45. that is 46 Ounces of the Salt-Water, will take up no more Room than 45 of the Freſh; or reciprocally 45 Pints of Salt-Water, weighs as much as 46 of Freſh.

But the Proportion of Brine-Water to Freſh, I found to be near 13 to 12. Suppoſing, therefore, G, H, to repreſent the Sea, and F, I, the Summit of the Mountain above the Sea, F, M, a Cavern in the Earth, beginning at the Bottom of the Sea, and terminated at the Top of the Mountain; L, M, the Sand at the Bottom, through which the Water is, as it were, ſtrained, ſo as that the Freſher Parts are only permitted to tranſude, and the Saline kept back: If, therefore, the Proportion to G, M, to F, M, be as 45 to 46, then may

the Cylinder of Salt-Water G, M, make the Cylinder of Freſh-Water to riſe as high as E, and to run over at N.

It is not much to the Purpoſe in this Place, to examine or confute the Opinion of thoſe who affirm, that the Depth of the Sea is no more in Perpendicular than the Height of the Mountains above it, there being few, if any, that have experimentally known the Perpendicular of either: It is ſufficient for the Purpoſe in hand, that the Gravity of Salt-Water is ſuch, when compared with Freſh, that it will raiſe it higher than its firſt Level, and that agreeably to the ſo often repeated Laws of Hydroſtaticks; which when added to what has been before ſet down concerning Filtration, ſubterraneous Heat, *&c.* will make the Aſcent of Water to the Tops of high Mountains the leſs difficult and ſurprizing.

Nor is there Room here to determine, whether there may not be other Cauſes of the Separation of the Freſh-Water from the Salt; as that, perhaps, ſome Parts of the Earth through which it is to paſs, may contain a Salt, that mixing and uniting with the Sea-Salt, may precipitate it, much after the ſame Manner as the alkazite and acid Salts mix with and precipitate each other in the Preparation of *Tartarum Vitriolatum*; neither can it be exactly known, whether the exceeding Cold, which muſt accordingly be at the Bottom of the Water, may not help towards this Separation, ſince 'tis found, that any Quantity of warm Water is able to diſſolve and contain more Salt, than the ſame Quantity of cold; inſomuch, that Brines ſtrongly impregnated by Heat, do ſuffer much of their Salt to ſubſide and chryſtalize about the Bottom and Sides: Neither is it known, whether the exceeding Preſſure of the Parts of Water one againſt another, may not keep the Salt from deſcending to the very Bottom, as finding little or no Room to inſert it ſelf between thoſe Parts protruded ſo violently together; or elſe ſqueeze it upwards into the ſuperior Part of the Sea, where it may more eaſily obtain Room for it ſelf, amongſt the Parts of Water, where there reſides more Heat and leſs Preſſure: To which Opinion ſome Geographical Writers ſeem to incline us, when they write of the drawing of Freſh-Water from the Bottom of the Sea, where it is naturally ſalt above.

But a Fifth Power, by which Water may be made to aſcend to the Tops of high Hills, is by Attraction, a Principle (as the ingenious Mr. *Hawksbee* has it) which governs far and wide in Nature, and by which moſt of its Phenomena are explained; which Attraction has been attempted to be ſolved ſeveral Ways: Some attribute it to the *impeded or diminiſhed Action of the Air;* others to the *Innixion, or Reſting of the Parts of the Fluid* on the Pores and Points

Points of Glaſs, or other Bodies, through which it paſſes; and others (of which the learned *Hook* in his *Micographia* juſt mentioned, is one) from the Congruity or Incongruity of the Parts of Matter one to another; all which being couched in hard and unintelligible Terms, which would rather confound than inſtruct my Reader, I can only ſay this, that 'tis *plain there is ſuch a Power in Nature, by which the Parts of Matter do tend to each other*; and that not only in the *larger Portions of it, but in thoſe which are more minute and inſenſible.*

To paſs by then all the curious Definitions of the Attraction here ſpoken of, and which is one Cauſe of the Aſcent of Liquids in ſmall Tubes, and conſequently of the Riſe of Springs to the Tops of Hills, let A, B, C, D, Figure V. Tab. ſeq. be a ſmall Tube perpendicularly immers'd in a Liquid whoſe Horizontal Surface is E, C, D, F.

The Parts of the Liquid a, a, b, b, adjoining to the Concave Surface of the Tube, are ſtrongly attracted by it, and that in a Direction perpendicular to the Sides of the cylinderick Glaſs; or (which is all one) parallel to E, F, the Surface of the Liquid.

Now the Particles a, a, b, b, gravitating in Directions perpendicular to E, F, (that is, parallel to A, C, and B, D,) the Sides of the Tube: By Means of the Attraction it comes to paſs, that the Particles a, a, b, b, have all of them a much leſs Momentum, or gravitating Force, than otherwiſe it would have, were the Attraction away. Therefore the Parts of the Fluid which lie immediately upon them, are much leſs preſſed upon than otherwiſe they would be.

And although the Particles d, d, lie farther off towards the Middle of the Tube, yet in a very minute and ſlender one, (ſuch as is here mentioned,) they are near enough to be within the Reach of the powerful Attraction of the Surface, ſo far as to be in ſome Meaſure influenced thereby, either immediately or ſuddenly, by the Means of the Particles a, a, b, b, which are ſtrongly urged towards the Glaſs, and do (by the general Law) attract the neigbouring Particles d, d, towards themſelves.

Upon theſe Accounts, the Momenta of all thoſe Particles, comprehended within the Circumference of the lower Baſis of the Tube, being much leſſened, the Fluid which lies directly under 'em, is proportionably leſs preſſed.

But the Parts of the Fluid f, f, f, f, which lie between the Surface E, C, D, F, and the Bottom of the Tube are at more remote Diſtances from the Sides of the Tube, than its Semi-Diameter; theſe Particles, I ſay, being out of the Reach of any ſuch Attraction, do

gravitate with their Force, or Momentum, on the Parts which lie under them: Therefore it appears, that by the Immerſion of the ſmall Tube into the Liquids, the Equilibrium is deſtroyed between thoſe Parts of the Liquid lying within the Circumference of the lower Baſis, and thoſe that are without. And ſo by the Laws of Hydroſtaticks, the Liquid muſt riſe within the Surface of the Tube; for the ſtronger Fluid (ſuppoſe Salt-Water or Freſh) will ſtill preſs in upon the Weaker, and force it away before it, (as has been already demonſtrated by Figure IV. Tab. ſeq.) that is, the Particles about a, a, b, b, principally, and next to them, the Particles about d, d, muſt neceſſarily give Way to the Particles below them, which are urged on by the ſuperior Momentum of the Particles which come from the aforeſaid remote Diſtances about f, f, f, f; from whence it follows, that thoſe Particles about a, a, b, b, muſt neceſſarily aſcend higher in the Tube, as to e, e, e, e.

When they are riſen higher, the Attraction to the Sides of the Tube will take place as before, and by leſſening their Momenta, with reſpect to thoſe below them, will give a new Occaſion to the external Fluid, to inſinuate it ſelf within the Bottom of the little Tube, and conſequently puſh thoſe Particles ſtill up higher as to g, g, g, g.

Thus by the continual Action of the ſame Cauſe, the ſame Effect follows, and the Liquor continues to aſcend in the Tube, till it comes to a certain determinate Height, where it keeps its Station, and that by the ſame Laws which brought it thither.

And this I take (with great Submiſſion) to be a ſatisfactory Account of the Reaſon of this Phenomenon, and ſerves to ſhew the Manner and Way by which Liquids may be conceived to riſe (not only) in ſmall Tubes, and in Caſes of a minute Nature, but alſo in thoſe larger Bodies of Water, which riſe through the Crannies and Pores of the Earth, *&c.*

And having thus ſhewn the Methods by which Water may aſcend by the Aſſiſtance of ſubterraneous Filtration, Attraction, or more properly ſpeaking, by the Aſcent of Liquors in the Capillary or ſmall Tubes of Aſhes in the open Air, and in Vacuo; it follows, that I endeavour to demonſtrate that the Sea does lie as high, or higher in many Places, than the Land does; and that conſequently the Laws of Hydroſtacy have more Force in this great Work of Nature, than its Oppoſers, or thoſe who are diffident of its Power, generally ſuppoſe it has, eſpecially if to it be added the additional Gravitation and Preſſures of the Moon and Atmoſphere in Storms, High Tides, and turbulent Weather, *&c.*

That

THAT the Sea, and many large Rivers are higher in ſome Places, and at ſome certain Times, than the general Level of the Earth is, eſpecially in high Tides, is not only probable, but very viſible to any that ſhall duly and carefully conſider it; and that it is near as high in meeting of the Tides in the Middle of the Ocean, as the general Run of Hills, is no leſs plain to thoſe that have ever tryed it by Levels.

DOCTOR *Plott*, page 155. of his oft quoted *Treatiſe of Springs*, ſays, that the River *Trent* lies higher in the Counties of *Stafford*, *Darby*, *Nottingham*, and *Lincoln*, than the River *Dane*, *Don*, or *Dun*, which is in *Cheſhire*, *Lincoln*, and *Yorkſhire*, does; from which it is inferred, that the *Iriſh* lifts up its Head higher than that which we call the *Deucalidon Sea*: And according to the Authority of many ancient Mathematicians and Philoſophers, (as *Cratothenes* by *Strabo* relates,) it is affirm'd, that at the City of *Corinth* the Sea was much higher than that of the *Saronichus* near *Cenchrea*, a Town of *Pelleponeſus*, ſo that it frightened *Demetrius Poliocertes* (who otherwiſe was determined to have dug away the *Iſthmus*) in ſuch a Manner, that he left off his Deſign.

To the ſame Reaſon alſo (to wit, that of the *Ionian* being higher than the *Ægean Sea*) it was owing, that *Julius Cæſar*, *Caligula*, and *Nero*, having began, deſiſted from advancing that Work, as *Joh. Bapt. Riccioli Geograph. & Hydograph. Reformatæ*, *Lib.* I. *cap.* 16. ſets down.

ON this Account alſo it was, that *Seſoſtris* King of *Egypt*, *Darius* of *Perſia*, *Ptolomy*, and after them (as *C. Plinius Secundus*, in his Natural Hiſtory, *Lib.* II. *cap.* 29. likewiſe ſets down) the *Ægyptian* Sultans, and laſt of all, the *Turkiſh* Emperors; and whoever was Prince in their reſpective Times, who had deſigned to attempt the Cutting through the *Arabian Iſthmus*, which was between the *Red-Sea*, *Nile*, or *Mediterranean*. But having found by the *Ægyptian* Mathematicians that the *Red-Sea* was three Cubits higher than the Land of *Ægypt*, were afraid, leaſt that Country ſhould be overflowed by a perpetual Deluge of Water.

NOR does this appear to be ſo amongſt the Ancients, only ſince *Cabæus*, in his Treatiſe of Meteors, *Lib.* I. Text 9. Queſtion 9. and Text 73. teaches, that it was manifeſt, even to common Sight, that the Gulph of *Geneva* is much higher than the *Adriatick* Sea; for if any one will take the Pains to aſcend the Mountain of *Bochetta*, it is manifeſt (ſays he) by Inſpection only, that the ſaid Sea of *Geneva*, which directs its Courſe by *Serraval*, where it keeps to its Level, from thence to *Tartara*, where it is a kind of a flat or gentle declining Sea; and from thence to *Papia*, where its Declivity is greater;

er; till at laft of all, it is ftill lower in the Gulph of *Venice*. And having fo changed the Order of Nature, the Sea of *Geneva* is there lower than that of the *Adriatick*; though there are many which have affirmed the contrary.

Ricciolus (in his *Geograph.* & *Hydrograph. Lib.* i. *cap.* 16.) affirms, moreover, that he was informed by the Fathers of the Society of *Jefus*, that in the Mountains which are adjacent to the *Ifthmus* of *Panama*, (from whence one may take a View both North and South of the *American* Sea,) it is manifeft, that the Sea runs much higher at *Nombre-de-dios*, than it does at *Panama*.

From all which it appears, and this is the Reafon, why the Bottom of fome Seas are higher than others. Neither is this any new Thing, but fuch as has been long ago obferved by *Ariftotle* himfelf: For he affirms, not only that fome Seas are higher than others, but that moft Rivers flow from the Weft, becaufe the Earth is there higher than in other Parts of the World, for which fee his *Treatife of Meteorology, Lib.* II. *Cap.* 1.) From this Caufe alfo it is, that *Fromondus*, as well as *Van Helmont*, confefs, that the Tides which flow from the North to the South, run fwifter than any where, although the Wind be againft it: And fo fanguine is *Helmont* in this Matter, that though he allows the terraqueous Globe is turned from the Eaft to the Weft, and that it is fpherical; yet for the fame Reafon he proceeds to deny, that its Figure is turned from North to South, but argues that it is there rather eclyptical, and not round, from the Obfervations of thofe who fail a good Way towards the North-Pole, who have afferted, that they ought to have feen the Sun fooner by a whole Month, if this united Body of Earth and Water was perfectly fpherical; which Effect, as it greatly exceeds thofe Limits of Darknefs, ought in all Reafon, as it appears to me, to be from the greater Elevation of the northernly Regions, above thofe of the South. An Inftance of this is Fact in the *Mediterranean* Sea, and in other Regions adjoining to it, as the aforefaid *Van Helmont*, in his *Ortus Medicinæ*, *Cap.* xi. *pag.* 34, 35. *Edit. Venetiis Anno* 1651. fets down: And how can it be otherwife, when the Northern flow into the *Atlantick*, or Weftern and the *Atlantick* into the *Mediterranean* Seas? Whereas the Current of the *Volga*, (if there be any fubterraneous Correfpondence of the *Cafpian* with the *Euxine* Sea,) the *Danube*, *Tanais*, and *Borifthenes*, caufe that all thofe Rivers which wander through fuch vaft Tracts of Land from the North, and are carried in a continual Declivity all the Way, clearly to demonftrate, that the Place to which they go, is much lower than the Northern Plains from whence they proceed;

the

he Seas whereof are lifted up ſo high, as that they may eaſily ſupply the Springs which are in the higheſt of the Southern Mountains.

But not to detain my Reader any longer in Purſuit of diſtant Enquiries, it may be proved from that Convexity which is in the Middle of the Sea itſelf, that at the Meeting of the Tides from the Shores from each Side, the Waters lie as high as moſt ordinary high Grounds where Springs break out do: Of this I have my ſelf made Obſervations from the Point of *St. Katherine's*, and other Places in the Iſle of *Wight*, which I ſhall by-and-by relate.

I Know that Monſieur *Rohault* * in his Phyſicks, ridicules the Notion of thoſe who ſay, that the Sea lies higher than Land, and calls it a very abſurd Notion; for then, ſays he, it muſt follow, *That Rivers do not decline, but run up Hill.* But when we conſider the great Difference there is between high Water-Mark and the low, in ſome Places no leſs than ten, fifteen, or twenty Foot, and in others more, eſpecially in high Tides and Fluxes of Water, 'tis not difficult to account for the eaſy Paſſage and Deſcent of Water at thoſe Times, an Obſervation ſo common, that I need not enlarge upon it.

But that the Sea in general (at leaſt the middle Part of it) lies rounder than the Land, is obvious in a great many Inſtances; eſpecially in one Obſervation which I have (as is juſt now hinted at) made in the Iſle of *Wight* ſome Years, and ſince much improved. The firſt Intimation which I had of it, was the Paſſage of a Ship out of thoſe Coaſts directly croſs for thoſe of *France*; where for ſome Leagues we could ſee the Ship very plain, but on continuing our View a great while, we at laſt diſcovered the Ship to diſappear by Degrees; firſt the main Bulk, then the lower, and at laſt the Top Sails. And all this in a very little Time, not half an Hour, at moſt.

This occaſioned another Obſervation, ſome Time afterwards in a pretty clear Day, and when the Water was near at its loweſt Ebb, and about thirty Foot lower than the Eminence on which we ſtood; then by the Help of an indifferent Level, and indeed a worſe Teleſcope, we found that the horizontal Line from the Place where we ſtood, was intercepted by the Surface of the Water; on which Account we moved up into more advanced Ground twenty or thirty Foot higher, and then we could juſt ſurvey the higheſt Part of the Water; and upon advancing ſtill higher, could by the Help of our Glaſſes, indifferent as they were, diſcover ſomething like Land on the other Side, which

---

* Vid. Rohault's *Phyſicks*, Cap. X. *Paragraph* 4. *Page* 417. *of Dr.* Clark's *Edition* Quod Maris ſuperficiis iſtis locis altior ſit; quo nihil dici poteſt abſurdius, ſequeretur enim flumina non declivi, ſed acclivi Curſu ad Mare reverti.

which we took to be the Coaſts of *France*; which in very clear Weather, and with good Glaſſes, may be ſeen at any Time there. And what made it remarkable was, that on the other Side of the Hill, which was about two Miles Diſtance from the Place where thoſe Obſervations were made, and as near as we could gueſs, (for we had not Time to make the Experiment,) the Springs cut at near that Level.

But if it be granted that the World is ſpherical, and that the Superficies of Water is ſpherical alſo, the Center of whoſe Sphere is the ſame with that of the Earth, (as *Archimedes*, in his two Books *de Inſidentibus Humido*, which is rendered in *Latin* by the learned *Barrow* before nam'd, *Lib.* I. Prop. 2. aſſerts,) and that the Center of Gravity is but a very little Diſtance from the Center of Magnitude; Water is of ſo light a Nature, that if that which is in one Part be carried to another Part, which is a great Way off, into any Hill in that Part; the Water which is one, will ſo exſuperate the higheſt Hill which is in the other, *i. e.* that is far more diſtant from the Center of Gravity, than the Top of the higheſt Mountain can be; that I can't underſtand (ſays the learned *Plott*) what ſhould hinder, why Water ſhould not of its own Accord (contrary to all exterior Force, ſuch as is demonſtrable by the Laws of Hydroſtacy) aſcend to the Tip-top of the higheſt Mountain, that is any where extant in the World, when its Level is more elated, *i. e.* farther diſtant from the Center of Gravity, than the Top of the higheſt Mountain can be: And if we accurately conſider the terraqueous Globe, we ſhall truly find the ſame unequal Difference of the Sea and Land, as there is betwixt the Center of Gravity and the Center of Magnitude; that it is neceſſary it ſhould recede as much (though more might be ſaid) as the Top of the *Mar de Zur*, or *Pacifique*, is diſtant ftom the Bottom. For that Sea, if you take it from the Shores of the River *Sinis*, you may ſuppoſe it to extend it ſelf between the Longitude of 150 Degrees, and that of 160; from which you may collect, that it takes up one third Part of the Globe, and leaves the two other Parts of the Earth; ſo that if you ſuppoſe it affords ſo many, or ſuch great Profundities, or Inequalities in the Bottom of this Sea, as are extant on the Mountains oppoſite to that Land, it will be very eaſy to underſtand how Water may be raiſed to the Top of any of thoſe Mountains.

Neither can it be here objected, that if the Center of Gravity ſhould be ſo far diſtant from the Center of Magnitude, but that it muſt neceſſarily happen it muſt drown a great Part of *Aſia* and *America*, whilſt it endeavours to keep to its Equilibrium, or Level; for the Shores of all thoſe Seas being filled with Creeks or Rocks, which being, moreover, but a little higher than the Border or Bounds

of

of the Sea, although the Hill of Waters which is within appears to be gibboſe, the Waters at the ſame Time riſing to great Heights, (that ſhould not God Almighty, in his due Time interpoſe, *who has ſet Bounds to the Waters, that they may not paſs over, that they turn not again to cover the Earth*; * *And unto the Sea, he ſaid, hither-to ſhalt thou go, but no farther*; *and here ſhall thy proud Waves be ſtopp'd*, †) thoſe miſerable Countries muſt of Neceſſity be drown'd.

And if the Sea, conſider'd in a State of Quietude, can do ſo much, how much more will it effect, when it is in a turbid or troubleſome State, *When its Waters are gather'd together, as in an Heap*; ‡ *When the Lord ſhews his Wonders in the Deep, and raiſeth up the ſtormy Wind, which lifteth up the Waves thereof*, ſo that *they mount up to Heaven, and then go down again to the Depths.* §

To all that has been ſaid on this Head, namely, of the forcing of Waters through the ſubterraneous Ducts and Channels of the Earth, by the unequal Height and Preſſures of Water in ſeveral Parts of the Ocean, &c. may be added, the Effects which proceed from the Flux and Reflux of the Sea, which is generally allow'd to proceed from the Gravitation of the Moon on the Atmoſphere ; ſuch a Moon making ſuch a Tide, being a common Expreſſion amongſt all Navigators: But whether her proper Action be to raiſe the Sea's Surface above, or depreſs it below its natural Level, ſeems not, perhaps, ſo eaſy to determine, ſince its Motion, alternately up and down, may be occaſion'd by either, and is one undoubted Cauſe (amongſt many others) by which Water is agitated, and forc'd to riſe to the Tops of ſuch high Hills.

Those who won't allow the Original of Springs to be from the Sea, own, as does the Learned *Nienwentyte*, *Sect.* lxx. of his *Religious Philoſopher*, who ſays, " That the Waters of the Sea under " the Moon, or nearly under it, do on both Sides of the Globe, " raiſe an exceeding great and convex Mountain, which daily ſurround " the Earth. Now that this can't happen without diſturbing the " Sea, *even in its deepeſt Cavities, is certain* ;" and that Springs, which correſpond therewith through the Veins and Fiſſures of the Earth, ſhould not be affected alſo, is as much to be wonder'd at.

The Antients generally attributed to the Moon a Power of raiſing or ſwelling the Surface of the Ocean, after the Manner of boiling Water; whence it was called the *Æſtus*, or Ebullition of the Sea, which, as they held, was at once excited in the Parts directly under

I her

* Pſal. civ. 9.   † Job xxxviii. 11.   ‡ Pſal. xxxiii. 7.   § Pſal. cvii. 24, 25, 26.

her Meridian, and thoſe diametrically oppoſite to them; the former by her direct, this by her reflex'd Rays. Of this Opinion is *Ariſtotle*, in his Treatiſe *de Mundo*, *Cap.* 4. as alſo *Strabo*, *Pomponius Mela*, (as I find it in an antient Manuſcript,) *Pliny*, (in his *Natural Hiſtory*, *Lib.* ii. *Cap.* 97.) and others, who aſcribe the Original of Springs to Air, Vapours, *&c.* And *Pliny* pleaſantly calls the Moon *Sydus Avidum, trahenſque ſecum Hauſtu Maria*, &c.

To proceed with a learned Author on this Subject. The Moon's Orbit being over thoſe Parts of the terraqueous Globe which lie between the Tropicks, and where the largeſt Seas are, as ſhe paſſes over them, preſſes thoſe Particles of Matter which are underneath her, and they preſs the next under themſelves, and ſo the whole intermediate Air; and thereby at laſt the Waters of the Sea, and ſo cauſes the ſaid Water to riſe on each Side of that Part of the Sea which lies under her Orbit, that is, towards the North and South Parts of the World. Hence to us, who live in the Northern Parts, the Tide always comes from the South, becauſe the Moon's Orbit travels South of us: And on the like Account the Tide comes from the North, to thoſe which live in the Southern Parts of the World, becauſe the Moon's Orbit is North of them: And hence it is evident alſo, that the Tide muſt come ſo much ſooner or later to any Place, as it lies more or leſs diſtant from the Tropicks, or that Tract of the Sea, which is underneath the Moon's Orbit.

The Tide being thus caus'd by the Preſſure of the Moon, it plainly follows, that becauſe the Moon comes every Day to the Meridian of any Place fifty Minutes later than the Day before, therefore the Tide likewiſe muſt fall out fifty Minutes later every Day than the Day before, in reſpect of any particular Place.

Also the Moon is ſix Hours in coming from the Horizon of any Place to its Meridian, therefore it is obvious, that the Tide muſt be ſix Hours coming in; and in like Manner, becauſe the Moon is ſix Hours in going from the Meridian to the Horizon of any Place, therefore the Tide muſt be the ſame Time in going out; where it is obvious, that as the Preſſure of the Moon begins in reſpect of any particular Place ſo ſoon as ſhe comes to its Horizon, ſo her Preſſure continually increaſes, till ſhe comes to the Meridian of that Place; and conſequently the Tide ſtill riſes higher and higher, till ſhe comes to the ſaid Meridian; which, as the Moon leaves again, ſo her Preſſure decreaſes; and conſequently the Tide ſinks lower and lower.

Moreover, it being agreeable to the Laws of Staticks, (as is found by Experiments,) for heavy Bodies to gravitate ſo much more as they come nearer to the Center of the Earth; hence the Reaſon why

why the Tides are bigger at the New and Full Moons, than at the Quarters, is eaſily aſſign'd, namely, the Moon's being at her Change and Full nearer to the Earth than at her Quarters.

Again it is obſerv'd, that as the Tides at the Change and Full of the Moon are bigger than at any other Time of the Month, ſo the Tides at the Change and Full of the Moon about the Equinox, are bigger than thoſe at any other Time of the Year; which may be accounted for by the Moon's being then over the middle Part of the Ocean, which is under the celeſtial Equator; and conſequently, by its Preſſure thereon, making a greater Quantity of Water to recede to each Side, *viz.* Northwards and Southwards, than when ſhe preſſes on one Side of the Equator, and ſo not on the Middle of the Ocean.

It remains to be obſerv'd, that it is demonſtrable by the Principles of Staticks, that the Moon does cauſe the Seas to ſwell, or, in one Word, the Tide not only in that Part of the Sea which ſhe is over, but alſo in the Part oppoſite thereto. And hence it comes to paſs, that there be two Tides every twenty five Hours, namely, becauſe in that Time the Moon going from any Meridian, returns to it again; and conſequently cauſes one Tide whilſt ſhe is in the upper Hemiſphere, and another whilſt ſhe is in the lower Hemiſphere.

But if we conſider the Flowings of the Tide, and proceed to account for the Courſe of it, by the Rotation of the Earth, how greatly muſt ſuch a Rotation contribute to the forcing Water through the Fiſſures and Chaſms, or, in other Words, through the Veins and Arteries of the Earth?

And here, before I end this Chapter, it will not be improper for me to take a View of what the learned and inquiſitive Dr. *Woodward*, in his *Natural Hiſtory of the Earth*, *Part.* iii. *p.* 131, &c. has ſet down, in relation to Springs; for though his Account be rather phyſical than mechanical, depending on the Doctrine of ſubterraneous or central Fires, yet, as he tells us, he had procured the Judgment of all thoſe Perſons on whoſe Fidelity he might rely, join'd to the Obſervations he had made himſelf. There is no Doubt, but his Enquiries are juſt in the main, though he may not account for the Aſcent or Riſe of Springs in the Manner they require.

In the firſt Place he proves, "That there is a mighty Collection of " Water in the Bowels of the Earth, conſtituting an huge Orb in the " interior or central Parts of it, upon the Surface of which the ter- " reſtial Strata are expanded; that this is the ſame which *Moſes*, (and " I add other Writers,) in Holy Writ, calls the great Deep, and the " antient Poets *Erebus* and *Tartarus*.

" *Secondly*, That the Water of this huge Orb communicates with
" that of the Ocean, by Means of certain Tubes or Chaſms paſ-
" ſing betwixt it and the Bottom of the Ocean; that they have the
" ſame common Center, round which the Water of both of them is
" compil'd and arrang'd; but in ſuch a Manner, that the ordinary
" Surface of that Orb is not level with that of the Ocean, nor at ſo
" great a Diſtance from the Center as that is, it being for the moſt
" part reſtrain'd and depreſs'd by the Strata of Earth lying upon it;
" but wherever thoſe Strata are broken, or are ſo lax and poreous, that
" Water can pervade them, there the Water of the ſaid Orb does
" aſcend, filling up all the Fiſſures whereunto it can get Admiſſion
" or Entrance, ſaturiting all the Interſtices and Pores of the Earth,
" Stone, or other Matter, all round the Globe, quite up to the Le-
" vel of the Surface of the Ocean.

" *Thirdly*, That there is a perpetual and inceſſant Circulation of
" Water in the Atmoſphere, ariſing from the Globe, in Form of Va-
" pour, and falling down again in Rain, Dew, Hail, and Snow;
" that the Quantity of Water thus riſing and falling is equal, as
" much returning back in Rain, *&c.* to the whole terraqueous Globe, as
" was exhaled from it in Vapours; that though the Water thus ri-
" ſing and falling, be certain and conſtant as to the whole, yet it va-
" ries in the ſeveral Parts of the Globe, by reaſon that the Vapours
" floating in the Atmoſphere, ſail in Clouds from Place to Place,
" and are not reſtored down again in a perpendicular Manner, upon
" the ſame preciſe Tract of Land, or Sea, or both together, from
" which they aroſe, but any other, indifferently; ſo that ſome Regi-
" ons receive more back in Rain, than they ſend up in Vapours; as,
" on the contrary, others ſend up more in Vapour, than they receive
" in Rain. Nay, the very ſame Region, at one and the ſame Seaſon,
" ſends up more in Vapours, than it receives in Rain; and at another,
" receives more Rain than it ſends up in Vapours. But the Exceſſes
" of one Region and Seaſon compenſating the Defects of the others,
" the Quantity riſing and falling upon the whole Globe is equal,
" however different it may be in the ſeveral Parts of it.

" *Fourthly*, That the Rain which falls upon the Earth, partly
" runs off into Rivers, and thence into the Sea, and partly ſinks down,
" (though not very deep,) into the Earth, inſinuating it ſelf into
" the Interſtices of the Sand, Gravel, or other Matter of the exteri-
" or or uppermoſt Strata, whence ſome of it paſſes on, (I ſay,) into
" Land-Springs, Wells, and Grotoes, and ſtagnates there, till 'tis by
" Degrees exhaled again: Some of it glides into the perpendicular In-
" tervals of the ſolid Strata; where, if there be no Out-let or Paſſage

" to

" to the Surface, it ſtagnates as the other does; but if there be ſuch " Out-lets, 'tis by them refunded and ſent forth, (as was more particularly explain'd in the Account relating to Sir *Thomas Willoughby*'s Coal Works in the laſt Chapter,) though but rarely with the " ordinary Water of Springs and Rivers: And the reſt, which, by " reaſon of the Compactneſs of the terreſtrial Matter underneath, cannot make its Way to Wells, the perpendicular Fiſſures, or the like " Exits, only ſaturites the uppermoſt Strata, and in Time remounts " up again in Vapour into the Atmoſphere.

To all which he adds, and which I place by Way of Corollary, *Firſt*, " That though Rains do thus fall into, and augment Springs " and Rivers, yet neither the one nor the other do derive the Water " which they ordinarily refund from Rains, notwithſtanding what very many learned Men have believ'd.

" Nor *Secondly*, That Springs and Rivers do not proceed from " Vapours rais'd out of the Sea by the Sun, and born thence by " Winds into Mountains, and there condens'd, as a modern ingenious " Writer is of the Opinion.

" And *Thirdly*, That the before mentioned great ſubterraneous " Magazine, (with its Partner the Ocean,) is the ſtanding Fund and " Promptuary which ſupplies Water to the Surface of the Earth, as " well Springs and Rivers, as Vapours and Rain.

" *Laſtly*, He proceeds to aſſert, That there is a nearly uniform and " conſtant Fire or Heat, diſſeminated through the whole Body of " Earth, and eſpecially the interior Parts of it. But this Account is " ſo interwoven with phyſical Ideas, that it will be too tedious to inſert in this Place; nor can I (I muſt confeſs) rightly underſtand " it, though *Deſcartes*, *Rohault*, and others, maintain it with great " Reſolution."

But before we draw to a Concluſion of this long and laborious Enquiry into a Part of Nature ſo uſeful and beneficial to Mankind, as this is, it will not be improper to take a ſhort Survey of what Authors have ſaid of that Deluge, with which the World was ſo remarkably deſtroy'd, and from whence it was ſuppos'd that thoſe Waters were deriv'd: And here I think, the Contenders for the Hypotheſes, that Rain, *&c.* was the only Cauſe of it, are at a great Loſs.

The general Account that we find of it in Sacred Writ, is taken from *Geneſis*, Cap. vii. 11. *That in the ſix hundredth Year of* Noah's *Life, in the ſecond Month, the ſeventeenth Day of the Month, the ſame Day, were all the Fountains of the great Deep* (though the

Maintainers of Rain allow us none) ***broken up, and the Windows of Heaven were open'd.***

From whence ſeveral Conjectures have ariſen; ſome imagining, that a Quantity of * Water ſufficient to make ſuch a Deluge, was created upon that Occaſion; and when the Buſineſs was done, all diſbanded again, and annihilated. Others ſuppoſe a Converſion of Air and Atmoſphere into Water, to ſerve the Turn. Many of them were for fetching down I know not what ſuper-celeſtial Waters for that Purpoſe. And *Deſcartes* merrily enough, and wide enough from the Principles of Reaſon, fancied (in his *Princ. Philoſ. Lib.* iv.) that the World at that Time fell all to Pieces, and ſo contracting itſelf (a ſtrange Way of arguing) into a leſſer Room than it originally had, was the Reaſon that a leſs Quantity of Water might ſurround and encompaſs it, with more to the ſame Purpoſe, all equally wide of Truth, and the Mind of the Sacred Writer.

The ingenious Mr. *Ray*, in his Treatiſe *of the Diſſolution of the World*, ſays, *p*. 99. " That this Deluge was from the Centers of the " Earth being chang'd, and ſet nearer to the Center or Middle of " our Continent; whereupon the *Atlantick* and *Pacifique* Oceans muſt " needs preſs upon the ſubterraneous Abyſs, and ſo, by Mediation " thereof, force the Water upwards, and at laſt compel it to run " out at thoſe wide Mouths and Apertures made by the divine Power " in breaking up the Fountains of the Deep." Which, by-the-by, is a Confeſſion that there were ſuch Paſſages then made and form'd; and why they ſhould not continue ever ſince, we are not told. And to proceed to our curious Author, (though he argued much for the Derivation of Springs from Rain, yet he was without any great Concern for the Succeſs of his Hypotheſis, as he himſelf tells us, *p*. 101.) And in the Page before that ſays, " That the divine Power " might at that Time, by the Inſtrumentality, of ſome natural Agent " to us at preſent unknown, ſo depreſs the Surface of the Ocean, as " to force the Waters of the Abyſs through the forementioned Chan- " nels and Apertures, and ſo make them a partial and concurrent " Cauſe of the Deluge." And he agrees further, " That there are ſome- " times in the Courſe of Nature, extraordinary Preſſures upon the " Surface of the Sea, which force the Water outwards upon the " Shores to a great Height;" which is (I think) as good as granting what we have been long explaining, I mean, as to the Correſpondence and Aſcent of Water from ſubterraneous Cauſes.

Dr.

---

* *For the Illuſtration of this, ſee* Part iii. p. 176. *of Mr.* Woodward's Natural Hiſtory of the Earth.

Dr. *Burnet*, in his *Theory of the Earth*, *Lib.* i. *Cap.* 2. conſidering how unſucceſsful the Attempts of thoſe who were gone before him had prov'd, and having himſelf alſo employ'd his laſt and utmoſt Endeavours to find out Water for the vulgar Deluge, he prepares for a Surrender, and ſays, " That to find out Water ſufficient " for this Effect, as it is generally underſtood and explain'd, is im-" poſſible." Not conſidering, that beſides the Rains which then fell, when the Windows of Heaven were open'd, that the great Abyſs alſo ſurrender'd its Water; and though it might riſe fifteen Cubits high above the Surface of the Earth, as by common Tradition it is ſuppos'd to do, yet that there might be Water enough for ſuch a Purpoſe, is evident enough. Nor does it follow, (if there were ſo many Hills as there are now,) but that the Water might guſh out there, and drown all the lower Valleys, (to which Places the Inhabitants of all Ages have repair'd, that they might live out of the Winds that reign'd above:) I ſay, ſuch a Deluge is not inconſiſtent to this Riſe of Water, which I have been all along explaining, but rather makes much for it: And that thoſe Vents, and ſuch a Communication and Correſpondence as I have been all along maintaining, might have their Enlargements, if not firſt Riſe from thence, is not improbable to ſuppoſe.

From all which, and a thouſand more Reaſons that might be produc'd, it is evident, that all perennial Springs may, and do derive their Source from the Sea and ſubterraneous Cauſes, &c.

CHAP. IV.

Of irregular Springs; and the Method by which they are tranſmitted to the Surface of the Earth, loſe their ſaline Properties.

HITHERTO we have diſcours'd only on thoſe Springs which are regular and perennial, or, in other Words, thoſe which flow in a regular Manner, and without any Intermiſſion: But there are other Queries to be anſwer'd in the Phænomenon of Springs, which naturally fall in this Place, namely, How it comes to paſs, that there are ſometimes Salt Springs, which lie much higher than the Superficies of the Sea itſelf? and then, How it comes to paſs that Springs do not run faſter and ſlower, according to the different Height

of the Cylinder of Sea-Water, by the Ebbing and Flowing of the Sea?

As to the firſt, it may be anſwered, in ſhort, that the Freſh-Water may receive again a ſaline Tincture near the Superficies of the Earth, by paſſing through ſome Salt Mines, or elſe many of the ſaline Particles of the Sea may be kept back, though not all. And as to the ſecond, Why Springs do not run faſter and ſlower, according to the varying Height of the Cylinder of Sea-Water, by the Ebbing and Flowing of the Sea? ſince the Water is loweſt in many Springs and Ponds, at the ſame Time it is higheſt in the Sea or River; and the Water is higheſt or moſt flowing in the Spring or Pond? at the Time of Low-Water in the Sea or River; as alſo why the Water of many Pools or Brooks are higheſt in the dry Summer, and loweſt in the Winter rainy Seaſons? theſe and ſome other irregular Productions of Springs, I now come to conſider of:

THE firſt is one found by Dr. *Plott* himſelf in the Pariſh of *Whittington* in the County of *Stafford*, near a Place, called by the Name of *Hangermore-Slade*, which, as this learned Author relates, (*p.* 14. of his Treatiſe *de Origine Fontium*,) and which was the common Report of that Country, never flow'd but upon the Approach of ſome Scarcity of Corn; but at other moiſt Seaſons, when it might, or ought to abound, it was entirely deſtitute of Water; ſuch was the Year 1680. though there had been near a whole Month's Rain before the Time he obſerv'd it. But when it did break out, (which was ſometimes ſcarce once in an Age,) it ſcarce flow'd above thirty Perches; but forthwith it diſappear'd again, and was ſuck'd up and loſt in ſome ſandy Ground.

THE ſame Thing happens in a Place, call'd *Aſhwood*, in the Pariſh of *King's-Swinford*, near *Swindon* in the ſame County, which flows not (according to common Tradition) unleſs there is like to be a ſubſequent Penury of Corn; but when it does flow, it is with as great a Noiſe, as the rattling and claſhing of Iron; and ſo terrible was the Sound thereof, that they report ſome Thieves that harbour'd thereabouts being ſtruck, as it were, with the Terror of a guilty Conſcience, immediately ran away. Not unlike to this is a Well in the Peak of *Derby*, call'd *Weeding-Well*, which, as the ingenious *Cotton*, in his *Wonders of the Peak*, *p.* 26. tells us, bellow'd out a hoarſe Sound, which it does at ſuch uncertain Periods of Time, that it is difficult to aſſign the Day, much leſs the Hour of its Fluxion. Of the Method of its Flowing, the acute *Hobbes* of *Malmsbury*, who was, I think, Tutor to the then Marquis of *Hartington*, afterwards

terwards Duke of *Devonſhire*,) has given an Account in his Poem on the Wonders of the *Peak*.

Fons hic temporibus non tollitur (ut mare) certis
Æſtibus his nullam præfigit Ephemeris horam.

This was a Specimen of *Hobbs*'s Averſion to the ſaid Wells, owing its Affluence to the Sea; but the ingenious *Cotton* ſoon retorts it back again,

Fertur in arva ruens hic ſemper limpidus Amnis,
Et punis, nunquam pluviis hyemalibus Auctus.
De Mirab. Pecci. Pag. 29.

But not to detain my Reader too long with Things of ſo little Moment, the famous horary Fountain of *Luſus* in *France*, (as related by *Emanuel Maignan*, in his *Perſpective* of *Tholouſe* in *Gallia Narbonenſis*, *Lib.* i. *Prop.* 1. *Sec.* 3.) exactly increaſes itſelf by little and little, yet not without the Noiſe of mighty ruſhing Waters; and by-and-by flows out into a large River; and then by the ſame Degrees it roſe ſubſides again; and at laſt grows quiet, and quite dry. This, *Du Bartas* ſays, continues four Months; but *Gaſſendus* ſays, only three; and that it breaks forth only in *May*, *June*, and *July*.

Natural Hiſtories produce an infinite Number of theſe irregular Springs; but that which *Pliny Junior*, *Lib.* 4. *Epiſt. ult.* relates to be in *Agro Comenſi*, as he calls it, the Country of *Coma* in *France*, which is three Days in its Increaſe and Decreaſe, and *Gaſſendus*, in his *Phyſicks*, *Lib.* iii. *cap.* 7. ſays, that the *Niger*, a River of *Africa*, and the *Ganges*, increaſe and decreaſe in certain ſtated Seaſons; and the ſame *Gaſſendus* mentions a Spring in *Colle Martienſe*, as he calls it, which flows and reflows eight Times in every Hour. The ſame Thing happens likewiſe by the ſmall Village of *Kilken* in *Flintſhire*, who, as the learned *Therret* in his *Prin. ver. Nat.* *Pag.* 222. flows and reflows reciprocally every four Hours: To this may be added what is ſaid of the great River *Nile*, which begins to decreaſe about the 24th of *September*, and ſenſibly diminiſhes till the Beginning of *May* following; when it becomes ſo languid and ſo little, that it ſeems rather to be ſtagnate, than to flow at all. But in *June* and *July* it begins to increaſe again, and ſo goes on till about the 17th of *September*, according to their (but the 24th of the

ſame Month, according to our) Calculation ; at which Time thoſe Inundations happen, with which *Ægypt* is ſo wonderfully enriched.

A Full and particular Account of this *Nile*, and other Rivers, we have from *Varennius*, *Lib.* i. *Prop.* xx. *Page* 249. with which other Authors alſo agree, which beginning its Inundations about the 17th of *June*, and increaſe forty Days ; and the ſame Time again in its Decreaſe, covering every Thing but the Hills ; at which Time the Cities which are built thereon look like ſo many Iſlands. And all this, by the By, happens, tho' there are few or no Rains which fall in all that Country.

I Shall not trouble my Reader with the Account which *Seneca*, who, from the Opinions of the *Greek* Phyſicians, wrote a learned Treatiſe concerning Springs, none of which, as *Varrennius* obſerves, is true ; becauſe in thoſe Times no Body went out of *Europe* to thoſe Fountains, becauſe they were very remote from *Egypt* ; but lately (as ſays *Varrennius*) the Cauſe of thoſe Inundations are explained, and the true Cauſe found out by the *Portugueſe*, *Dutch*, and *Engliſh*, which hold Commerce in the Kingdoms of *Congo*, *Angola*, *Moromotapa*, &c. and by them it is known, that the Fountains from which the *Nile* proceeds, is the great Lake *Zair*, ſituate on the Borders of *Africa*, between the eaſtern and weſtern Shore, under the 10th Degree from the Equator, Southward.

Adjoining to this Lake there are many Ridges of Mountains, which, from their Circularity, are called *Lunæ Montes*, or Mountains of the Moon ; and one Ridge they call *Seth* ; in the Middle of which Mountains lies this Lake : But becauſe theſe Mountains are turned ſoutherly from the Equator, it is Winter with them when it is Summer with us ; but being but a little Way diſtant from the Equator, they perceive no Cold, but have Rain in the room of Snow conſtantly two Hours in a Day, before and after Noon, in the Kingdom of *Congo*, &c. and in the Mountains which join to thoſe Kingdoms, it rains almoſt continually at that Time of Year, that the Ridges of thoſe Mountains look as if they reached the Clouds ; from which the Rains running down in great Torrents, flow altogether into the Lake *Zair* ; and from thence (but by what Paſſages *Varennius* does not tell us) into the Current of the *Nile*, that the *Cuama*, and other Rivers which flow out of this Lake, overflows likewiſe, but not in ſo great Plenty : The *Zair* nevertheleſs flows every Year at theſe Seaſons, as the *Nile* does. And from hence is the manifeſt Cauſe of the Inundation of the *Nile*, (to wit,) to that great Plenty of Water, which fall from thoſe Hills ; the chief Occaſion of which is owing to the continual Rains that fall on the aforementioned

aforementioned Hills, and from thence run down into that Lake; which Rains happen about the Middle of *March* or *April*, becauſe from the 4th of *March* to the 21ſt, it is Autumn with them, and then theſe Rains begin; but they are leſs vehement in *May*, *June*, and *July*, than before; in *Auguſt* and *September* they are ſtill leſs, and in *September* they ceaſe quite.

But let not the Maintainers of Rain and Vapours from hence argue, that the Inundation before mentioned, is wholly to be aſcribed to their Hypotheſis: Thoſe who are on the other Side of the Queſtion always allow, that the Rains which are ſupped up by the Sun fall on high Hills, and then run down precipitately into Valleys and Rivers, and from thence into the Sea; by which Circulation it is that the Sea is undoubtedly maintain'd; but then they deny, (and that with great Reaſon,) that theſe Rains ſink into the Crevices of the Ground, and conſtitute Springs.

To this Account of the *Nile*, may be added thoſe which flow out of the Lake *Chiurny* into the Bay of *Bengal*, and paſſing through the Kingdoms of *Pegu*, *Siam*, and other Places, flows through the Country of *Siamenſis*, called *Menan*. This Inundation happens in *September*, *October*, and *November*; at which Time the Fields are cover'd with Water, *&c.* Another is called the *Silver River*, in *Brazil*, which flows at the ſame Time that the *Nile* does.

Another is the River *Macon* in *Gamboice*, which overflows in the Summer Months. Another is the River *Parana*, or *Paranaguaſa*, which flows in the ſame Manner as the *Nile* and the *Silver River* in *Braſil* does; on which Account ſome will have it to be the very *Silver River* itſelf.

Others there are, as the *Euphrates*, which, at certain ſtated Seaſons of the Year, overflows *Meſopotamia*; and another River there is in *Numidia*, called *Sus*, which overflows in the Winter; and all theſe owe their Fluctuations to one Cauſe, (to wit,) to the Abundance of Rains, Snows, that then fall, and run into theſe Lakes, or Sea. To avoid Prolixity, the River * *Bibara*, near *Paris* in *France*, ſwells to that Degree, ſometimes without any Rains, at leaſt not thoſe which are extraordinary and unuſual, (to be ſure by high Tides, as about *London*, and other Places it does,) that it lays waſte the adjacent Suburbs of S. *Marcellus*. All which I give in *Varennius*'s

* Fluvius Bibara in Franciâ prope Lutetiam, aliquando ſine ullis Pluviis, aut certe non inuſitatis, ſic intumeſcit ut adjecente ſuburbio S. Marcelli inferat magnam vaſtitatem. Vid. Varenn. Geograph. General. Lib. i. Prop. xx. Pag. 260.

rennius's own Words, becauſe the River he has mentioned is not to be found in any of my Dictionaries.

But to ſhew that we need not go ſo far for Examples of this Kind, there are Springs of our own, (as the learned *Cambden*, and after him *Speed*, relates,) which obſerve an irregular Motion; one whereof is a Well upon the River *Agmore* in *Glamorganſhire*, and near unto *Newton*, which ebbs and flows quite contrary to the Motion of the Sea, being almoſt empty at Full-Sea, but full at Low-Water; which may come, as that curious Obſerver Dr. *Hooke* obſerves, *Page* 27. of *Micographica*, tells us, from the Bottom of a Sea very remote from thoſe Parts, and where the Tides are much differing from thoſe of the approximate Shores.

But to proceed: Another Example of the Irregularity of Springs is found near the River *Loder*, or *Lowther*, in *Weſtmoreland*, which ebbs and flows many Times in a Day: This likewiſe, ſays Dr. *Hooke*, may proceed from its being ſupply'd by many Channels coming from ſeveral Parts of the Sea, lying ſufficiently diſtant aſunder, to have the Times of High-Water differing enough from one another; ſo as that whenſoever it ſhall be High-Water over any of thoſe Places where theſe Channels begin, it ſhall likewiſe be ſo in the Well. All Regularities, as well as Irregularities in the Fluction of Springs, may (as I ſaid before) proceed from divers Ducts coming from very diſtant Parts of the Sea, ſo as that it may be in one Place High, in another Low-Water; and ſo, by that Means, the Spring may be equally ſupply'd at all Times; or elſe thoſe Ducts may be ſo ſtrait or narrow, that the Water not having ſo ready and free a Paſſage through it, cannot, upon ſo ſhort and quick a Mutation of Preſſure, be able to produce any ſenſible Effects at ſuch a Diſtance.

But the beſt Account that has yet been given of this Irregularity of Springs, is that which the learned *Deſaguliers*, in the *Tranſactions* of the *Royal Society* for *July*, *Auguſt*, and *September*, *Anno* 1724. *Numb.* 384. has given concerning the *Lambourne* Spring, which is in the County of *Berks*, and another at or near *Greenhive* in the County of *Kent*; the firſt of which, as Dr. *Plott*, in his Treatiſe *de Origine Fontium*, *Page* 41. ſays, was communicated to him by *John Hippeſly* Eſq; a Neighbour in that Place, which flows more plentifully in the Summer than in the Winter; and which was more conſiderable, that in the memorable Drought, which happened in the Year 1681. when other Rivers were almoſt dried up, theſe Springs and Rivulets were higher than even they uſed to be at that Time of the Year; nor did they, till about the Mid-

dle of *September* (the uſual Time of their Abatement) fail: When, nevertheleſs, a great Quantity of Rain had fallen before that Time, yet there could not be found ſo much as a Drop of Water in the Bowels of the Earth thereabouts, till towards the Middle of *February*: At that Time the Springs began to flow again as ùſual.

But to proceed with our learned and curious Hydroſtatician, he tells us, that *Hero Alexandrinus*, and other Hydraulick Writers, have deſcribed a Cup, (called a *Tantalus* from its Effects,) which will hold any Liquor very well when it is not filled above a certain Height marked in the Cup, which is performed by a Syphon concealed therein to make the Effect the more ſurprizing.

The Cup A B, Fig. 6. Tab. ſeq. has a viſible Syphon C E D in it, the Cup Fig. 7. has its Syphon more concealed, as it is carried up into the Handle; but in that of Fig. VIII. in which is the Figure of a Man, repreſenting *Tantalus* in the Fable, who was up to the Chin in Water yet could not drink; where the whole Syphon (tho' now laid open by the Section) might be concealed. Any of thoſe Cups, ſays our Author, will hold Water very well, provided they are not filled above the Line FG; for then not only the Liquor, which is above F G, will run out, but all the Liquor in the Cup as low as D, the Orifice of the ſhort Leg of the Syphon.

To explain this, that ingenious Gentleman has produced an Experiment, Fig. 9. ead. Tab. wherein the Veſſel a b c d is placed an open wooden Box, A B C D, filled with Water as high as the Line L M; another Box or Plug, E F G H, made tight, and containing Weight to ſink it, is made to let down into the Water between the Partition I K, and the End A B of the Box above mentioned; but when it is not to preſs the Water up to I, (as it does when let down,) it is drawn out of the Water by the Weight M, which pulls it up by the Bar i k, faſtened to a Leaver, moving round the Center L.

When, by Means of the Plug the Water in the Space A B K I, is puſhed up to I O, by paſſing under K, it runs out through the Spout P Q, (whoſe Paſſage is gauged by a little Sluice P p,) and falls into the Veſſel R S, made of an oblong Figure, like a Fiſh-Pond, and having a Scyphon at S, ſo as to make it a *Tantalus*, or in the Nature of the Cups above mentioned.

Let the Weight M pull up the Plug E F G H, and the Water having filled R S, will run down below the Orifice P to m.

The *Tantalus* R S, beginning to run out as ſoon as full, will, for the Reaſons above given, continue to run out till it is all emptied; and as it diſcharges itſelf into another *Tantalus* T V, whoſe Scyphon

is

is at V. this laſt *Tantalus*, will alſo, when full, begin to run out, and its Water go down to x Y o.

If the Plug be let gradually down, as ſoon as the Water begins to run out of the laſt *Tantalus* T V, (and the firſt *Tantalus* R P be covered ſo as to be concealed from Sight,) it will appear to the Lookers-on, that the Cavity T V, repreſenting a Pond near an ebbing and flowing River, as there is credible Information there is one at *Greenhive* in *Kent*, between *London* and *Graveſend*, always riſes whilſt the Water at N O (or the Tide) falls to L M; and always ſinks whilſt the Water at L M, or the Tide riſes at O L.

This has alſo been the Occaſion of another Experiment, (Fig. ix.) which let it be the Water in the Box, A B C D, not made uſe of, only the Veſſel Z be filled every half Hour, it will empty itſelf in the Space of a Quarter of an Hour, falling like Rain, and dropping alſo through the Leaden Platform e f into the hidden *Tantalus* R S, which will not begin to run till this artificial Rain is over: Then in a Quarter of an Hour more the *Tantalus* R S will have emptied itſelf into the viſible *Tantalus* T V, which will be filling all the Time after Z has done running, or in the dry Seaſon,) and as ſoon as T V is full, it will begin to run through its Syphon V, at the End of the half Hour, when the Veſſel Z, or Seive, runs again, that is, at the Return of the Rainy Seaſon.

And this laſt Experiment may be eaſily apply'd to thoſe Ponds, or thoſe Brooks, that are high in dry Weather, and low in wet; of which Kind there is one at *Lambourn* in *Berkſhire*, as there is credible Information; but this, I muſt own, I have not ſeen.

If it be objected, that ſuch Ponds are full for ſome Time, which a *Tantalus* cannot be, becauſe it begins to run out as ſoon as full; that may be eaſily ſolved, by ſuppoſing the hidden *Tantalus* (or intermediate Cavity between the River and Pond,) to contain more Water than the viſible one, provided it does not contain ſo much as not to be emptied before the Return of the Tide.

The ſame Solution will ſerve for wet and dry Seaſons, only ſuppoſing the Cavities larger.

If it be asked where the Water of the viſible *Tantalus* near a River can run; it may be anſwered, That all this may happen, tho' the ſecond or loweſt *Tantalus* ſhould have its Bottom higher than the Low-Water Mark in the River. And for the Syphons which are of a particular Make in the Cup, though ſuch be not ſuppoſed in the Earth, yet any long Paſſage riſing in the Middle will anſwer the End. (See Fig. x.) where A B C D repreſents the Channel of a River, A D the High Water, and G H the

the Low-Water Mark, Z I a Paſſage from the River to the Cavity I K L M N, or firſt or hidden *Tantalus*, L M Q, the Scyphon of the firſt *Tantalus*, running into the ſecond, or viſible Pond O Q R P, which by its Syphon R S V, runs out into low Grounds that may be above the Low-Water Mark G H, and the Bottom K L of the firſt *Tantalus* may be above the Top of the laſt, whoſe Level is the Line W W.

A B C D Y O Q R P V H is the Section of the Surface of the Earth.

The Irregularity of Springs being thus accounted for, it may not be improper in the next Place to anſwer ſome few Objections which have been brought againſt the Opinion of thoſe who hold their Original from the Sea, I mean, as to their parting ſo eaſily with thoſe ſaline Particles with which by Nature they abound.

Those who argue againſt the Derivation of Springs from the Sea, and would aſcribe it to Rains, Vapours, &c. are very eaſily perſwaded to believe how that Separation is effected in the ſublimer Regions of the Air, in which they agree, that Sea-Water, exhaled by the Power of the Sun, is in its Sublimation ſtripped of all its ſaline Particles, not only fixed, but volatile, before it can or does deſcend again in Rain; but when they are, I ſay, made to believe how eaſy this is effected, (*in ſublimoribus*,) if I may uſe the Words of a learned Phyſician on this Head, how comes it to paſs that they can't conceive how Nature, who is regular and uniform in all her Proceedings, ſhould not effect the ſame below, as ſhe does above?

Besides all, it is, indeed, much more eaſy to account for the Methods by which it is done within, than without the Surface of the Earth, not only by Percolation, but by Evaporation. Alſo as *Ariſtotle*, with whom our learned Countryman *Lydiat*, in his *Diſquiſit. Phyſiolog. de Origine Fontium, Cap.* 2. *in initio*, agrees; it being an abſurd Thought, that the ſame Effect can't be produced in the obſcure Paſſages of the Earth, as is in the open Spaces of the Heavens, (to wit,) by that innate Heat which labours in the Bowels, and cauſes a Reak in the coldeſt Winter Months, and acts, perhaps, in a much more regular and uniform Manner than the Sun does, eſpecially in Winter, when Sublimations are more rare, and Rains moſt certain: For the effecting of which, as they can render no particular Method, why ſhould they, by Parity of Reaſon, expect the ſame from us?

But if we conſider the almoſt innumerable Degrees of Percolation and Evaporation, which Water undergoes in its Paſſage through the Body and Pores of the Earth, in four or five, or, perhaps, ſix or ſeven Thouſand Miles running, how many of its groſs Humours muſt

natural-

naturally ſubſide, and be ſtrained off in the Ducts and Tubes of the Earth? how gently the whole Maſs muſt be rarified by that ſubterraneous Heat? which is ſo viſible in all new-dug (as well as old) Cellars and Vaults, and evaporated and carried off in Lakes, and open Bodies of Water, ſo great, indeed, that a rational Man ought not to wonder how Sea-Water ſhall be thus ſtripped of its priſtine Humour.

To anſwer another Objection often made uſe of, namely, how comes it to paſs, that thoſe ſubterraneous Ducts, through which the aforeſaid Percolations are made, (if Salt be endued with ſuch an adherent Quality,) are not filled up with thoſe great Quantities of Matter, which muſt naturally ſubſide, or adhere thereto; ſince the Beginning of Things, and long ago filled up, and quite obſtructed.

To this may be anſwered, in a few Words, That it is in the firſt Place as probable that the ſaline Particles here underſtood are entirely excluded thoſe Tubes and Meanders, it having been before noted, that even the Bottom of Sea-Water, is much ſweeter than that at Top; as that it is certain in the next Place, that the Pores and Channels of the Earth, may be dilated and extended thereby; Sailors knowing, from ſad Experience, in a Scarcity of Freſh, when they are obliged to filtre their Salt-Water through a Veſſel full of Sand or Earth, by which Means it will be at firſt a little ſweeter; yet having repeated thoſe Strainings often, the Pores of the Earth will be ſo relaxed, that very little more of that priſtine Unpleaſantneſs will ſtick thereto. From whence it is certain, that thoſe Meanders, which have been in the Ground ſince the Beginning of Things, grow larger and larger, rather than fill up. And that thoſe Humours not being of a terrene Subſtance, either evaporate by Heat, or, by Way of Sudation, ſeparate themſelves from that which is Freſh, and perſpire into that muſcular ſpungy Subſtance with which the Earth is compoſed, ſtill leaving the main Arteries and Veins thereof open and at full Liberty, for that Conveyance and Aſcent of Water which we have been ſo long diſcourſing of.

And this is the Reaſon that Springs (as the Right Reverend and Learned *Stillingfleet*, in his *Origin. Sacr. Lib.* iii. *Cap.* 4. rightly obſerves) are not every where, and without Diſtinction found; but only every where in in its proper Channels, as the Blood in the Veſſels of Animals: For if you ſqueeze thoſe Animals in thoſe Parts, they will immediately emit Blood from thence; but if the Lancet happens amongſt the muſcular or more callous Parts of the Body, where no Blood is apt to follow ſuch an Inciſion, except it be made higher, or in another Place.

In

In like Manner you may dig to an incredible Depth in ſome Places, before you can fall upon Water; and in another Place, ſcarce a Stone's-throw from the former, you may find it plentiful enough, and that not far from the Superficies of the Earth. Of this many Examples might be produced, but eſpecially one, which our often quoted laborious Author *Plott*, in his natural Hiſtory of *Staffordſhire*, mentions to be at *Barlaſton*, near *Newcaſtle upon Tine*; where it is remarkable, that in the South Iſle of the Church, as often as they have Occaſion to dig any Grave, the ſame is immediately filled with Water, though it is covered from all the Rains which fall from above; but if you dig in any other Part of the Church, or in the Church-yard adjoining, it is there perfectly dry. And even ſo much farther remarkable was it, that a Gentleman of the *Bagnal* Family aſſured our Author, that he had a Well not far diſtant from thence, at leaſt ſixty ſix Foot deep, which affordedb ut little Water in the Winter, and ſcarce any in the Summer.

But there is in that County, ſays the ſame Author, another Inſtance that more plainly demonſtrates the Derivation of Fountain-Water through the Channels and Ducts of the Earth, (aſcending up therein as the Blood does in the Veins of Animals,) than any yet mentioned; and which the moſt ſagacious and learned Gentleman, *Walter Chetwynd*, of *Ingeſtre*, Eſquire, often related to him; that at what Time ſoever my Lord *Aſton* cleanſed the Ditches, which were in the Meadows in the ſubjected Plain between the River and the Town, which he uſed ſometimes to do, he plainly drew off the intercepted Water by that Means; which could not in the leaſt happen, unleſs the Water which run through ſuch Ducts and Channels directly from the *Sovo*, (for ſo he calls the River, I ſuppoſe, there running,) and was to be carried up into the Town.

And now we have a little expatiated on what was in the Beginning of this Treatiſe of Springs hinted at, I mean the Analogy that naturally occurs between the Macrocoſme and Microcoſme; it may not be amiſs to draw a ſhort Parallel of the Methods by which this great Work in Nature is effected.

I Imagine then that the Sea (which is ſubject to the Laws of Gravitation, and the Preſſure of the Moon and Atmoſphere thereon, as has been before demonſtrated) is the Fund from whence all Springs originally proceed. Now as the Blood, which proceeds from the Body by the Compreſſion and Dilation of the Heart, (being the Seat from which Life itſelf has its Exiſtence,) diſtributes itſelf through all the Ducts and Veins of the Body, in a due and regular Circulation; ſo does the Sea by the Gravitation and Compreſ-

fion of the aforementioned Powers, force on the Water through all the Chafms and Ducts of the Earth, receiving it again, being haften-ed in its Journey, and incorporated with and rarified by the Spirits and fubterraneous Effluviums it meets with in its long Paffage through it; and this Circulation and Afcent of Water through the Veins and Ducts of the Earth, can't in the leaft be wonder'd at, when we con-fider the Exellence and Power of that great Architect who firft framed the World, and all that is therein.

If we take a farther View of this Afcent of Springs, and compare them to the Afcent of Sap in Trees, which does not, indeed, according to the new Hypothefis, circulate, but afcend as the Water does in an artificial Syphon, perhaps, by the Laws of Rarefaction, Filtration, Attraction, or Pulfion, *&c.* how admirable, and yet how plain and eafy is it from them, the Fire-Engine, and other hydraulick Powers, to be accounted for? and in which is difcovered the violent Elafticity and Force there is of Steam, Vapour, Water, or any other Fluid, when compreffed or crowded into a little Room, which rifes from the Roots of Plants in fine Tubes and Veffels, far beyond the precife Laws of Hydroftaticks, (which do not admit of above 32 Foot,) even to 50, 60, or 70 Foot high, or more, from the great Force proceeding from the Rarefaction of the Juices in Plants, effected by the Sun, as the fubterraneous and more latent Heat of enclofed Fires are faid to fa-cilitate the Rife of Springs in the Ground?

And thus having, I think, undeniably proved, that Springs (efpecially thofe which are in *England*, and other Parts of *Europe*) do not derive their Caufes from Air, Vapour, nor Rain, but rife thro' the Earth by the Laws of Rarefaction, Filtration, Attraction, *&c.* confirmed by almoft an innumerable Number of Examples and Experiments, to be more plainly deducible from fubterraneous, than other Caufes above; I finifh all with what the Scriptures, thofe divine Oracles of Reafon, have delivered on this important Subject, which as a Chriftian, though an unworthy Member of that Body, I affent to and embrace, learning from *Gen.* viii. *v.* 2. *That the Fountains alfo of the Deep, and the Windows of Heaven were ftopt, and the Rain from Heaven was ftopt*; in which is feen a vifible Diftinction between Springs from the Deep, and Rains. *Job* xxxviii. Verfes 16. *Haft thou entered into the Springs of the Sea, or haft thou walked in Search of the Depth?* *Amos* ix. Verfe 6. *It is he that calleth* (or as it is in the Margin *that bundleth up the Waters of the Sea, and poureth them out upon the Face of the Earth.* And the Septuagint pofitively renders that Paffage in *Genefis*, Cap. ii. Verfes 5, 6. *That it was the River which*

which went out of Eden, which watered the Face of the Earth before Rains had fallen; though our Tranſlation ſays it was a Miſt which then roſe. And in *Ezekiel*, Chapter xxxi. Verſe 4. they render it, that it was (as Doctor *Plott* obſerves) *the Abyſs which ſent out Water for the watering of Plants.* And in like Manner, *Geneſis* vii. Verſe 11. it is ſaid, *That in that Day were all the Fountains of the Deep broken up, and the Windows*, (or as it is in the Margin,) *the Flood-Gates of Heaven were opened*; where is a manifeſt Diſtinction between the two Fountains of Rain above, and Sea-Water below. And in *Proverbs* viii. Verſe 28. he ſaith, *God has eſtabliſhed the Clouds above*; *when he ſtrengthened the Foundation of the Deep.* The ſame alſo may be found *Geneſis* xxxxix. Verſe 25. *In the Bleſſings which* Jacob *conferred on his Son* Joſeph, *even by the Almighty, who ſhall bleſs thee with Bleſſings from above, and of the Deep that lieth under.* And of this Opinion alſo was *Plato* and *Seneca*, the firſt in his *Phæd.* Pag. 112. and the laſt in his *Nat. Hiſt. Lib.* iii. *Cap.* 4, 5. who ſay, that that great Conflux of Waters which is derived from the Sea, is raiſed through the Syrtes, Quickſands, or Veins of the Earth from ſome immenſe deep Place. And this Gulph, ſays *Plato*, into which when all Rivers flow, they reflow again. And in *Job.* xxviii. *Verſe* 14. *The Depth ſaith it is not in me, and the Sea ſaith it is not with me*; all which import, that there is a Communication between thoſe two Places diſtant from Rain.

I Must own my ſelf ſomewhat concerned at the Pains which many great Men have taken to eradicate this ſerious and ſcriptural Truth; not that I think the Hills and Excreſcencies of the Earth are of no uſe in natural Cauſes, or a Blemiſh of the Creation, as many Atheiſts and Unthinking would believe: The Wiſdom of Providence is ſuch, that Hills are placed in that high and exalted Manner we ſee them, that whether Springs owe their Original to Rain, Vapours, or the Sea, they are nevertheleſs ſubſervient to the great End which God Almighty firſt deſigned them: Becauſe from theſe it is, that Water is conveyed with more Eaſe into the humble Plains below, than it would otherwiſe be. And that whatever Vapours, &c. may do, which fall on ſome Hills beyond Sea, and run down with ſuch Violence, as the learned *Halley* ſays, thoſe of the Mountains of the Moon, and others of an unknown Name in *Africa*, (from whence the *Nile* and other Rivers proceeds,) do, yet in the Regions we inhabit; it is plain there is no ſuch Thing, at leaſt ſo viſible, as that it ſhould make us ſwerve from thoſe ſerious and ſolid Truths of the Bible; nor that we may not conclude, as it is in *Eccl.* xi. 11.

That all Things which are of the Earth, ſhall turn to Earth again; and that which is of the Waters, ſhall return again into the Sea; and which is confirmed by one of the greateſt Philoſophers, as well as Princes, that the World ever produced; who tells us, *Eccleſ.* Chapter i. Verſe 7. *That all Rivers run into the Sea, yet the Sea is not full; unto the Place from whence Rivers come, thither they return*: Thus thoſe Springs run into the Rivers, from thence into the Sea, and then run back and preſs themſelves through the Earth again, until free Leave be given them to come abroad, or, like *Hannibal* in the *Alps*, to work themſelves a Way through.

CHAP. V.

Of the Method of diſcovering and ſearching for Springs; their Specifick Qualifications, and the like.

AUTHORS who have heretofore wrote of the Diſcovery and Production of Springs, have attributed it to divers Cauſes; ſometimes to Earthquakes, as was the River *Ladon*, between *Helis* and *Magelenpolis*: Some ſuppoſe it to be to ſubterraneous Fires, which cauſe them to burſt out. But the moſt remarkable Method in the Diſcovery of Springs, is as *Varennius* teſtifies, *Lib.* I. *Prop.* 21. *pag* 261. from a Swine which lay down and wallowed in the *Lunenburgh* Spring, the Hair of which, when the Sun aroſe, was by its drying Quality, ſo ſoon incruſtated and grown dry, that the Spectators ſaw a whitiſh Colour upon him, which when they obſerved more curiouſly, they ſaw to be white Salt; which cauſed them to have Recourſe to the Fountain, and forthwith they diſcovered and found out Springs, from which that City has ſince obtained all its Riches and Splendor: And ever ſince that, a Quadriparte-dry'd Hog has been kept in *Lunenburgh*, where the Parts hang upon a Beam, ſo waſted by Time, that there remains nothing to be ſeen but the Hide.

BUT to come nearer my Deſign: The ſame *Varennius*, in his *Geograph. General. Lib.* I. *Prop.* 23. *Cap.* 262. of the Elziver Edition, tells us from *Vitruvius*, *Lib.* VIII. *Cap.* 1. from whence alſo *Pliny* and *Palladius* have taken their Account, which *Beſſonus* has alſo added in the third Edition, printed *Anno* 1569. That if Fountains do not flow of their own Accord, their Heads are to be ſought for under Ground, and ſo collected together. Which Springs may be diſcovered in the following Manner: If you lay down on the

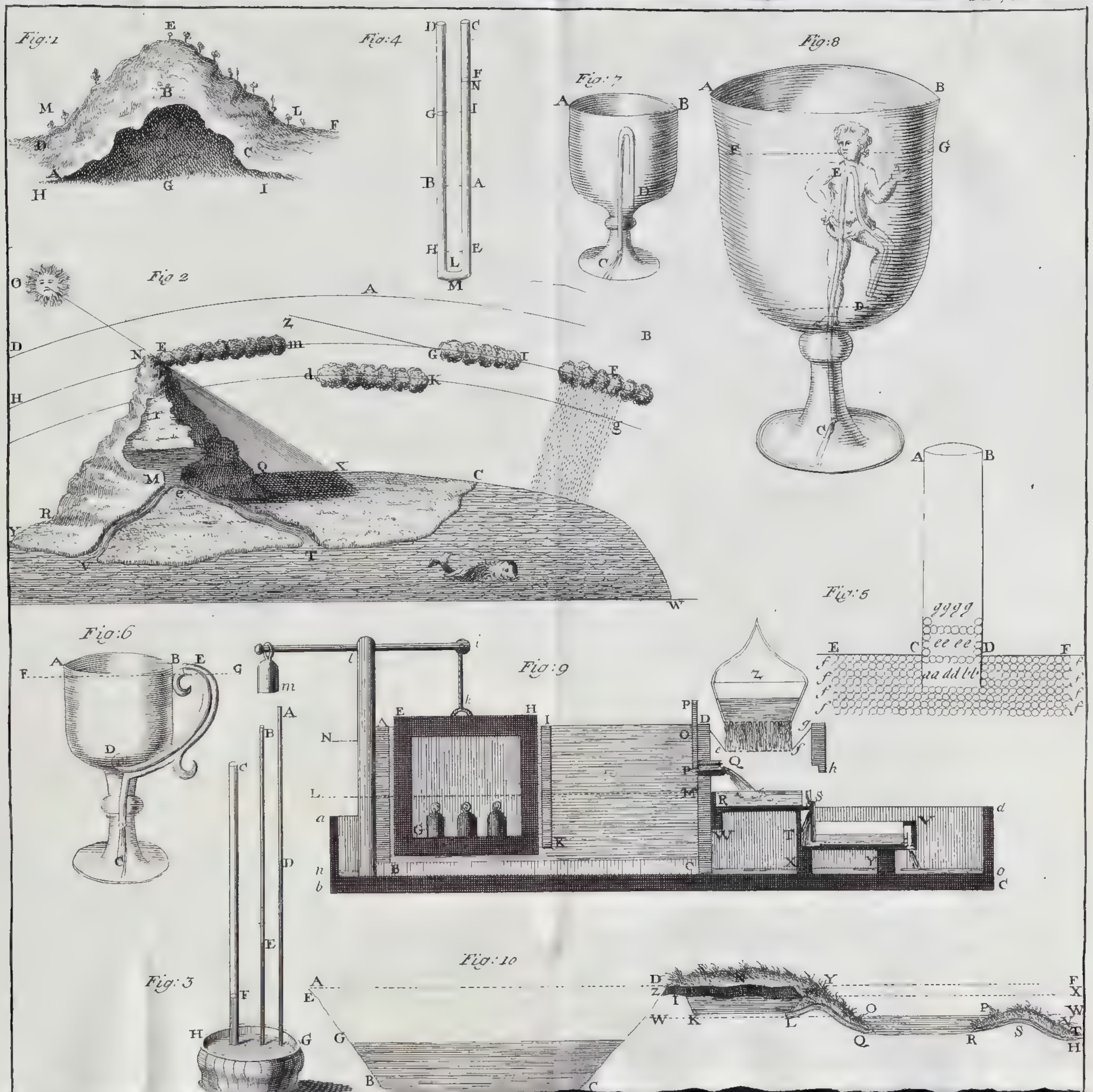


Fig:1
Fig:2
Fig:3
Fig:4
Fig:5
Fig:6
Fig:7
Fig:8
Fig:9
Fig:10

Ground before the Sun riſes on Places where you would ſeek for them, and having plac'd your Chin as cloſe as you can, till it is, as it were, propp'd by the Earth, ſo that the Country thereabouts may be plainly ſeen; for by this Poſition the Sight won't wander any higher than it ought: If you keep your Chin unmov'd, it will give a certain Definition and true Level of the Parts where you are placed, and in thoſe Places where you ſee Vapours gathering themſelves together, and riſing up into the Air, there you may dig; for this Sign never happens in a dry Place. Thoſe therefore who ſeek for Water, ſhould firſt conſider what the Places are in which Water is to be found. In the following Places Springs are certain and good: In Chalk (ſays ſome) it is fine, but riſes not very high, but (whatever the Antients thought of it) it is the beſt Water of all. In Sandy Gravel alſo it is fine; but if it is found in low Places, (theſe are generally Rain-Springs,) and then it will be muddy, and unſavoury; but in black Soils there are fine thin Diſtillations found, which are collected, as they ſubſide, from Winters Rains in clayey Grounds, and thoſe have the beſt of Taſtes: In Ground which is a clear Gravel, Springs abound but little, and the Veins are not certain; but thoſe are extraordinary ſweet. In large pebelly Gravel, and in Sand, Stone, or looſe Veins of Coal, they are more ſtable and certain; and theſe have all a good Taſte. They are Plenty alſo in red Stone, and good if they don't ſlip away, and run off through the Interventions thereof. They flow plentifully alſo under the Foot of Mountains, and in ſtony Places; theſe are very cold, but very healthy: But the Water which is found in champagnious open Places (ſuch is the Water in all ſtagnated Ponds) is thick, betwixt hot and cold, and not ſweet, unleſs it be that which ſprings out of the Bottoms of Mountains, and takes its Courſe into the Middle of large Plains: And where they are ſhaded with the Covering of Trees, there they excel the Sweetneſs of Mountain Springs.

Many other are the Signs where good Springs (according to the Antients, eſpecially * *Coronarius*) are found; who have intimated, that wherever the Twig Withy, Fleabane, Reeds, Trefoil, Pond-Graſs, and the Bull-Ruſh grow, in great Plenty, 'tis there you may moſt probably find Water; but Water, ſays the ſame Author, is to be found more conſtantly by the following Experiment.

Wherever you are deſirous of finding it with Certainty, there muſt a Ditch be made of three Foot deep, and taking a leaden Veſſel, or earthen Pot, made in the Form of a Semicircle, at Sunſet rub it

* Vid. Coronarius's *Agriculture*, *Lib.* ii. *Cap.* 4. *p.* 27.

it over with Oil; then prepare a Piece of Wool, half a Foot long, and waſhing it very carefully, and drying it afterwards, you are to bind on a ſmall Stone in the Middle of it, and fix it in the Middle of the Pot or Veſſel with Wax: Then turn the Mouth of the Pot downwards in the Trench you have thus caus'd to be dug, taking a particular Care, that after it is ſo turn'd the Wool may hang down in the Middle of the Veſſel; which done, you muſt cover your Veſſel with Earth a Foot thick, and keeping it ſo all Night. Uncover it in the Morning, before the Sun riſes; and if there be Water in the Place, you will perceive the Pot to have ſmall dewy Drops hanging on its Bottom, and the Wool to be wet.

If the Wool be very full of Water, and the Drops hanging on the Pot be very large, you may conclude you are not very far from the Spring; but if it be only moiſt, though there be a Spring in that Place, yet it lies very low, and not to be come at without a great Expence, and much Difficulty; but if none of theſe Symptoms appear, you muſt make the Experiment in another Place.

There are other Methods by which Water may be diſcover'd; as by obſerving the Nature of the Soil. If it be a black fat Soil, and abound with Pebbles of a black or yellowiſh Colour, there you need not fear the Want of Water; the ſame may be ſaid, if the Soil be glutinous or clayey; and alſo by the natural Produce of it, (as before,) you may diſcover where Springs are, as where Water-Plantain, the Sun-Flower, Reed-Graſs, or Oxbane, Brambles, or Shavegraſs, Calamint, Mat-Ruſhes, Maidenhair, Melilot, Sower Sorrel, or Ditch-Dock, Cinquefoil, Bloodwort, Nightſhade, Water Millfoil, Colts-foot, grow; and where they grow in greateſt Abundance, there you will find the largeſt Springs.

To this may be added what Mr. *Bradley*, in *Numb.* I. of one of his late *Miſcellany Papers* obſerves, from his ingenious Friend *Charles du Bois* Eſq; of the *Stellaria Aquatica* & *Saxifraga aurea*; which whether certain Tokens of Springs, a little Practice may determine.

Now as to Soils; thoſe which are black and deep, produce (as already noted from *Vitruvius*, *Pliny*, and others) the moſt durable and ſtrongeſt Waters; thoſe which are moſt clayey, are the wateriest, and the Waters are the ſweeteſt; though in *England* we generally ſuppoſe, that our Chalks produce the fineſt Water, as do many of our fine Sands that which is admirable, as I have often obſerv'd at *Spy-Pack*, near *Sandy-Lane*, the Seat of the *Bayntons*, on the Road to the *Bath*, where there is ſome of the fineſt ſweeteſt Water in the World, and on a fine light Sand, as may be obſerv'd by thoſe that paſs that Way. To proceed with the Antients;

Those

Those Waters that lie deepeſt are the ſweeteſt and moſt durable; for thoſe which are found near the Surface, moſt commonly proceed from Rain, and ceaſe with their Cauſe: Wherefore it is neceſſary to dig deep, till you come to the very Fountain-Head, and there you need not doubt of its being laſting and flowing continually, though there are, indeed, ſome Springs that lie within eight or ten Foot of the Surface, that are as durable as any of thoſe that lie twenty or thirty Fathom, and that in Countries where no River appears; but this is not ſo frequently to be met with, unleſs it is where Rivers do abound, which do, in a particular Manner, influence thoſe Wells that lie near them.

Some there are that try the following Experiment to find Water: They dig a Ditch a Foot broad, and three Foot deep, and about Noon hang a dry Sponge in the Middle thereof for three Hours, covering it cloſe with great Reeds, and if the Sponge, when taken thence is wet, they proceed to dig, aſſuring themſelves of Water; but if it be dry, it is in vain to dig or ſearch for it. *Corral*, ſays our aforenamed Author, pounded and caſt into Water corrects the Bitterneſs of it, and a Bag of Barley thrown into it has the ſame Effect.

Vitruvius, *Lib*. x. *Cap*. 6. ſays, that the Antients made ſeveral Conſervatories, out of which the Water paſſed (as may be ſuppoſed) very leiſurely one into another, reſerving the laſt for that out of which the Water was to be taken for uſe, and the others were for the Sediment which is in Water, particularly thoſe that are a little muddy: They likewiſe put Salt into their Water to make it more ſubtle.

Democritus, another Author of great Antiquity and Experience, as the aforementioned *Coronarius*, in his Writing concerning Agriculture, *Lib*. ii. *Cap*. 5. *Pag*. 29, has it, aſſures us, that thoſe who have taken their Obſervations from the Hydrophanticks, or Diſcoverers of Water, aver, that Flats or extenſive Plains, are commonly moſt deſtitute of Water, as riſing Grounds ſeldom fail of abounding therewith; and thoſe Eminencies that are the moſt ſhaded with Trees, have generally the greateſt Share thereof; and it is obſerveable, that thoſe Waters which are found in Plains, are moſt commonly, brackiſh; whereas thoſe that are diſcovered in an Eminence are generally ſweet, except they are changed by ſome accidental Cauſe, as Salt, Nitre, Allum, Sulphur, or the like.

The natural Cauſe of the aforegoing Effects may be thus aſſigned, *viz*. that the Sun always attracts the ſmalleſt and lighteſt Particles, out of the Water, and leaves the groſſeſt ſubſiding; wherefore the Sun

Sun lying all Day long upon the Plains, (and the Water being by its natural Level the leſs moving,) exhales the Moiſture, and diſolves it into Vapour. From whence it follows, that ſome Plains are almoſt deſtitute of Water in the hot Summer Months; and the ſmall Quantity which remains, is ſalt and unpleaſant to the Taſte, the ſweet and light Particles being drawn off from thoſe that are more groſs and unpleaſant; and to this may be aſſigned (ſays my ingenious Author) the ſaline Quality of the Sea: But the Sun ſhining only obliquely on the Sides, and Verticities of Hills, and the Cadence Motion or Fall of Water (call it which you will) being more precipitate from Hills and riſing Grounds, than from all low Levels and humble Plains, the Sun has not the ſame Influence on the firſt, as on the laſt, and, conſequently, the Water is not only the more plentiful, but alſo more pleaſant; and it is obſervable that thoſe Hills that are ſituate towards the North, abound with more Plenty of Water than thoſe that are ſituate towards the South; and thoſe that are ſhaded with Woods, than thoſe which are naked.

To conclude this Account; *Caſſiodorus*, and others, (as the ingenious Author of the *Theory and Practice of Gardening* has it,) ſet down, that wherever you can diſcover Swarms of ſmall Flies hovering and pitching about one and the ſame Place, that they are certain Signs that Water is there.

From this View into the Records of Antiquity, we ſee what the Antients have ſaid concerning the Method of Diſcovering of Water, moſt of which is agreeable to the Obſervations of modern Practitioners. The ſeveral Kinds of Weeds, in this Chapter before recited, are certain Indications that Water, (if it does not break out,) is near at Hand: And to this may be added, that thoſe Kinds of Herbs grow on moory black Land on the Sides of Hills, and where the Ground is mix'd with Pebbly Gravel or Rock, that is of a dusky, brown, ſandy Colour. But there is not a more certain Sign of Water in the World than where Alder-Wood grows naturally, and of its own Accord: Nor does the Oak diſdain to be an Inhabitant of thoſe moiſt Hills, there being (beſides Obſervations of that Kind made in other Places) an Oak in *Spy-Park*, before named, through the Roots of which there iſſues out at leaſt 200 Hogſheads of Water in a Day; and there are in that beautiful, (though now forlorn Place,) at leaſt thirty or forty of ſuch Springs, beſides innumerable others that lie without it.

After this ſo particular and ſuccinct an Account of the ancient and modern Obſervations for the Diſcovery of Springs, their Situation, *&c.* it will be requiſite that we proceed to the Operation it ſelf, ſuch as is founded not only on Speculation, but on the undoubted Force of Fact and Practice.

Those who have been converſant in Mines and Cole-Works obſerve, that there are (as I think is before ſlightly intimated) two Sorts of Springs; thoſe that lie near the Surface, and are ſuppos'd to proceed entirely from Rain; and thoſe that lie deeper, which proceed from a much more remote Cauſe. It would then be dangerous, in the firſt of theſe Caſes, to dig deeper than the Surface where they firſt appear, leaſt they ſhould take a wrong Current, and inſtead of breaking out Sideways, ſink beneath their Cauſe, and be loſt in the Crannies and Openings of ſuch Rocks of Stone and Gravel as lie contiguous thereto; but thoſe are either ſtronger or weaker, as they happen to lodge or fall on Earths that are in their Nature more or leſs glutinous and clayey, and conſequently tenacious of Water; or are otherwiſe of a more arenacious, gravelly, ſandy, or of a drying Chalk and whitiſh Earth, or, which is very common, of a flinty or hollow Subſtance; for contrary to the Opinion of ſome, otherwiſe very ingenious and good Reaſoners in a Cloſet, or in Books, 'tis to one or more of theſe Cauſes, and theſe only, that Springs abound more or leſs in any Country whatſoever. And theſe uppermoſt Springs you muſt ſeek after with Caution; but thoſe that lie lower you need not fear of injuring, as the many deep Wells lately made in ſeveral barren Places of *England* are a ſure Teſtimony.

When you have pitch'd upon a Place that is proper to bore for Water, by ſome one or more of the Signs I have laid down, be provided with a large Augar, that may be grafted at every five or ſix Foot; and having made a round or ſquare Hole on the Top of the Ground where you intend to bore, about three or four Foot wide, or more, to give Room for your Workmen to make their Experiment the better, you are to proceed; and when you have bored one Length of your Augar of four or five Foot, as aforeſaid, then graft on another Length, and ſo on, till you come down to the Water, every now and then pulling out your Augar, and cleanſing of it, to ſee what Soil you bore through.

But of theſe Kind of Augars, and the Way and Method of boring, you will be better inform'd at the Cole-Works of *Durham*, as *Newcaſtle*, *Sunderland*, *&c.* in the *North*, and at the Cole-Works in *York* and *Lancaſhire*; as alſo at thoſe of *Mendipp* in *Somerſetſhire*, where both Lead and Coal are dug; as alſo in *Derbyſhire*, and elſewhere.

I SHALL finiſh this Chapter when I have given, beſides an Obſervation or two about Wells, an Account which has been related to me with much Serioufneſs; and that was in *Spain*, when the Confederate Armies were there in the laſt Wars. When they wanted Water on their March, or otherwiſe, they dug down ſuch a Pit as I have been before deſcribing, and with the Muzzles of their Muskets have fired four or five Times down into the Ground, which has cauſed the Water to boil up immediately for their preſent Uſe. But I much doubt of ſuch Succeſs with us here in *England*, eſpecially in all upland and champian Ground, where alone Water is wanted.

BEFORE I conclude this Chapter it may not be improper to make a ſhort Enquiry into the Nature and Goodneſs of Water.

VARENNIUS, in his general Account of the Properties of Water, (*Cap.* xvii. *Prop.* 1.) lays it down as an undoubted Maxim, that there is no Water pure and elementary, but contains, or has mix'd with it, ſmall Particles of Matter, (ſuch as are found in all terreſtrial Bodies,) which (ſays he) is prov'd from the Difference there is in their Taſte, as well as from Diſtillation itſelf. And ſo all Phyſicians agree, that Water which is ſimple and unmix'd, has no Exiſtence in Nature; the Cauſe of which is the various and perpetual Agitation of the Particles of Matter of which all Bodies are compoſed. Mineral Waters in particular (ſays he) receive their ſpirituous Particles from the Mixture of thoſe which are hetereogenous or different from them; but Rains, and Air it ſelf, touching or preſſing upon Water, are compos'd of Particles very many and different from each other; from whence he infers, by way of Corollary, that all Waters are compos'd of Particles of a different Nature which are mix'd with them. And that I may explain him the better, I add, thoſe that are beſt for Plants with ſuch Particles as are nitrous and earthy, and which may be appropriated to all the general Purpoſes of Life, and thoſe which are more ſpirituous and Phyſical (being impregnated with Sulphur and the like) to all extraordinary Caſes, ſuch as acute Pains, Aches, and the like.

BUT I need not enlarge on the Intermixture or different Properties of Water, ſince that (eſpecially as it reſpects Vegetation) is ſo excellently well done by the learned Dr. *Woodward*, in an Eſſay of his, publiſh'd in the *Tranſactions of the* Royal Society, as well as to the curious *Examen* of the learned *Boyle*, and others, to which I refer my Reader. To proceed then to the different Denominations of this great Part of Nature.

SPI-

Spirituous Waters are chiefly call'd volatile, and are found in Minerals, but yet contain ſome fix'd Particles; but beſides them there are no notable Properties that may be extracted or drawn from them. From whence he concludes, that all watry Bodies take their Denomination from theſe two Properties, (*viz.*) fix'd or ſolid, volatile or ſpirituous; and theſe contain all of them Particles of a mineral Nature.

But to omit Minerals, and to proceed to thoſe Properties which are the moſt eſſential to the common Purpoſes of Life; the ſame ingenious Author, *Cap.* XVI. *Prop.* 24. of the aforementioned Treatiſe, as he has it from *Vitruvius*, that thoſe Waters which flow ſwiftly, and in an open Stream, are the beſt; that it ſhould be minded whether the Men which liv'd near thoſe Fountains, were ſtrong and luſty; and if they were of a Soldier's Mien, of a clear Complexion, not Bandy-Legg'd, nor Blear-Ey'd, thoſe Waters were the moſt to be approv'd of.

Also if the Fountains were new dug, and the Water ſprinkled on a *Corinthian*, or any other Veſſel made of good Braſs, if it left no Spots upon it, then that Water was the beſt in its Kind.

In like Manner, if ſuch Water was heated in any Cauldron or Braſs Pot, and afterwards left to ſettle, and be pour'd off, and that neither Sand, nor any other ſlimy Matter was found at the bottom of the ſaid Pot, or Cauldron, that then ſuch Water muſt be accounted good.

So alſo if any Legumes be put into a Veſſel, and ſet over a Fire, in ſuch Water, if thoſe Legumes are quickly boil'd, it is an Indication that the Water is good and healthy.

When you dig for a Well, great Care ought to be taken, not not only in ſtewing the Sides to keep the Earth from tumbling in upon the Workmen, but alſo to take Care that the Effluvia's of the Water (which if bad) do not hurt them; for it has been often remark'd, that the Water which is under the Earth, hath many bad Qualities, and emits Vapours, which often ſtiffle thoſe which work in the Well after they are dug, and the Water begins to gather together. To prevent which, the Ancients, as *Vitruvius* has it, *Lib.* x. *Chap.* 6. had this Precaution, To let a Lamp gently down into it, and if it extinguiſh'd it, they took it for an infallible Sign that the Water was bad; and I add, that this Care, and the curious Obſervance whether Water is good, or no, is of great Uſe to thoſe that would live and enjoy thoſe uninterrupted Scenes of Health, which alone make Life pleaſant; for a very worthy and honourable Nobleman of my Acquaintance in the County of *Southampton*, was obliged to deſiſt from Building, though on a lofty and noble Situation, on that Account.

C H A P. VI.

Of the Inſtruments proper for, and Method of taking the Levels or Falls of Water, from a Spring-Head to a Manſion-Houſe, Building, Reſervoir, Garden, Pond, &c. *And the Allowances to be made in Levelling, for the Curvature of the Earth, Deſcent of the Water, and the like.*

THE Original of Springs, with the Manner of finding them out, being thus ſet down, what follows next in Courſe is the taking the exact Levels, making proper Allowance for the Curvature of the Earth, and adjuſting the Fall or Current which is generally allow'd for the Deſcent of Water. But firſt, of the Inſtruments for that Purpoſe:

THE Ancients, as *Vitruvius*, *Lib.* viii. *Chap.* 6, writes, "made "uſe of an Inſtrument they called *Corrobates*, which was directed "by a Lead, and by Water when the Wind hinder'd them from "making uſe of the Lead; and allowed in the Channels or Sewers, "of the Aqueducts for every hundred Foot half a Foot of Decli- "nation or Sloping; and if any Hills were in their Way, they dug "thro' them, making Vents to give Air at convenient Diſtances."

THE ancienteſt Inſtrument us'd with us, as well as one of the moſt certain, is the *Water-Level*, deſcrib'd by *Blythe*, in his *Improvements of Husbandry*, (at the Beginning,) which muſt be own'd to be one of the beſt of all, in the operative Part, at leaſt of Works of the Kind we are now upon, provided the Weather be ſtill; but if it be Ruffling, it is like all other Inſtruments, difficult to uſe. However, with ſome Improvements I have made to it, which will be more particularly declared in ſome ſubſequent Pages of this Chapter, when I come to treat of the directing the Level in the making Trenches for conveying of Water, it will be eaſy to uſe.

BUT for the firſt taking of Levels, eſpecially thoſe which run any Diſtance, theſe that follow are in the moſt Eſteem amongſt the Ingenious:

IN the firſt Place, I ſhall not (in Regard to my Profeſſion as a Gardener) paſs by our common Garden *Level*, deſcrib'd as it is in Miniature, *Fig.* 1. *Tab ſeq.* where A A repreſents the two upper Sides of the *Level*, B B the under Sides, reſting on the

Heads

Heads of two Stakes, which I may call alſo by that Name of B B. And the Lead, which is faſtened to a fine Pack-thread, hanging from C towards D, holding a Plumb at a which when the *Level* is truly Horizontal, plays down through the dotted or prick'd Line. This Inſtrument, by the Help of the Boning-Staff P Q R of about four Foot and a half long, will diſpatch any Work or Labour of this Kind as well as any yet to come, though not ſo portable: But if you ſtick a Knife or Knives into the Stakes B B, any where towards the Top, and make them level to one another, by Application of the ſaid Boning-Staves, you may take any diſtant View when the Weather is fine and clear; and by ſticking the Knives *ad Libitum* into theſe Stakes, you may go on better than when you drive them down to any determinate Height, and the Work will diſpatch quicker.

In the Works of the celebrated Monſieur *Le Bion*, who is, or was Mathematical Inſtrument-Maker to the *French* King, I find a Teleſcope Plumb *Level*, (vid. *Fig.* 2. *Tab. ſeq.*) the Conſtruction of which, take as follows:

This Inſtrument (ſays *Le Bion*) is compos'd of two Branches joined together at Right Angles; whereof that carrying the Thread and Plummet is about a Foot and a half, or two Foot long.

This Thread is hung towards the Top of the Branch, at the Point 2; the middle of the Branch, where the Thread paſſes, is hollow, ſo that it may not touch in any Place but towards the Bottom, at the Place 3, where there is a little Blade of Silver, on which is drawn a Line perpendicular to the Teleſcope.

The ſaid Cavity is covered by two Pieces of Braſs, making, as it were, a kind of Caſe, leaſt the Wind ſhould agitate the Thread; for which Reaſon there is alſo a Glaſs-Covering to the Silver Blade, to the End that we may ſee when the Plummet plays upon the Perpendicular. The Teleſcope is faſtened to the other Branch, which is about two Foot long, and is made like other Teleſcopes. All the Exactneſs of this Inſtrument conſiſts in its having the Teleſcope at Right Angles with the Perpendicular.

This Inſtrument has alſo a Ball and Socket, as other Inſtruments of this Kind have; and there are ſome of them made of Braſs or Iron, whoſe Teleſcope, and the Cavity, in which is included the Thread carrying the Plummet, is about four or five Foot long, in order to level great Diſtances at once. The Teleſcope is about an Inch and a half Diameter, and the Caſe in which the Thread carrying the Plummet is encloſed, is about two Inches wide, and half an Inch thick. This Caſe is faſten'd (with Screws in the middle) to the Teleſcope, ſo that they may be at Right-Angles one to another; and at the two Ends of the Teleſcope are adjuſted two broad Circles, in which the

 Teleſcope

Telefcope exactly turns; which Circles being flat underneath, are faften'd to a ftrong Iron Rule.

THIS *Level* is fupported by three Legs, as other Inftruments are, faften'd into the Globe at D, under the Ball and Socket mark'd 4, where there is a Screw to make the Ball go ftiff; alfo there are two Openings, cover'd with Glaffes, enclofed in little Brafs Frames, which open fo that the Thread and the Plummet may be hung to the Top of the Cafe, and play upon two little Silver Blades in a Line drawn on them perpendicular to the Telefcope. Thefe Blades are placed againft the Openings of the Cafe, and the Telefcope is like that before fpoken of.

THE two little Inftruments mark'd F and H are *French Levels*, and are founded upon the fame Principles as the preceding ones; the Figures whereof are fufficient to fhew their Conftruction and Ufe.

AMONGST all the *Levels* which have been or may be produc'd, there is none which, for Portablenefs, Cheapnefs, and, I may add, Certainty and Difpatch, that exceeds that which I am about to defcribe in this Place, it being what any ordinary Countryman may make or purchafe for about eight or ten Shillings; whereas other *Levels* there are, and which will be neceffarily defcrib'd in the Series of this Chapter, which will coft five or fix Pounds.

LE BION has this amongft his Collection of curious Inftruments for Levelling; which he fays, is a Tube made of Brafs, or other like folid Matter, about three Foot long, and twelve or fifteen Lines Diameter, whofe Ends are turned up at Right Angles for receiving two Glafs Tubes, three or four Inches long, faften'd on them with Wax or Maftick; at the Middle, and underneath this Tube, is fixed a Ferril for placing it upon its Foot. This *Level*, though it be a very fimple one, is very commodious for levelling fmall Diftances. Thus far *Le Bion*.

BUT long before I faw this Defign from *France*, I remember to have feen one of the fame Kind in *England*, in the Hands of my very ingenious Friend Mr. *Jacob Wells*, of *Farringdon*, *Berks*, founded upon the fame Reafons, though not made exactly in the fame Manner as the former was; it confifted of a Piece of Heart of Oak, (if I remember right, for it was fome Years ago I faw it,) that was about two Inches fquare, in the middle of which, there was a large Groove, into which was fix'd (as I take it) a Tin Tube, of about two and half or three Foot long, being the Length of the Piece of Wood turn'd up at the End, into which, at a a, was put in two Tubes of Glafs, of an equal Length, reaching to b b; now into either End of the

Glafs

Glaſs Tubes, which are always open, you may pour in Water ſo high, 'till it reaches the prick'd Line c c, or thereabouts.

This Inſtrument may be fix'd on a Tripos, or a plain Table, or any other Inſtrument for Surveying, is ſlipp'd into it at B; and if you manage it with any kind of Dexterity or Diſcretion, it will immediately form a Level, as at c c, before mentioned, which though it be farther off, or nearer to a a, is not material; the Water which is in the Tube naturally reſting on a Level, over which you are to take your View.

But if you have a Mind to enlarge your View a great Way, you may frame in a little Poſt on one Side of your *Level* at O, which ſhall have a Screw fix'd into it at P, and may be either rais'd higher or lower at Pleaſure, as your Water is in the Tubes, through which you may have Sight to look at N° 2, 2. as you do through other *Levels*. The *Rationale* of this, and all *Levels* of this Kind, are, that Water naturally places it ſelf level; and therefore the Heighth of the Water in the Glaſs Tubes will be always the ſame, in reſpect to the Center of the Earth.

The next *Level*, I ſhall mention, is a common *Spirit-Level*, which which is deſcrib'd in Miniature, *Fig.* 4. *Tab. ſeq.* having a Bubble of Quickſilver, or, which is better, Spirit of Wine, or any other Liquor diſcoloured, to make it the more viſible. This Spirit being encloſ'd in a ſmall Glaſs Tube of two or three Lines Diameter, in a Piece of Wood or Braſs, about two or three Inches ſquare, has Degrees on it on the Upper at a, running each Way towards the Ends b b, in equal Parts as far as 10; now the Length of the Bubble may be ſuch, as to reach from three to three Degrees each Way, or from four to four, and ſo on. But whereſoever it reaches, it is proper it ſhould be an equal Number of Degrees, diſtant from the Center a, be it what they will. This ſtands upon three Legs, and has generally a Ball and Socket, as other Inſtruments of this Kind have, and is uſed after the ſame Manner. There are, that have Teleſcopes to them, one of which I ſhall produce by and by; and ſhall now proceed to thoſe made of Air, which are not as yet (at leaſt as I have ſeen) common in *England*.

In the Works of the ingenious *Le Bion*, before mentioned, there are the Draughts of two Kinds of the *Air-Level*, one whereof without, and the other with a Teleſcope annex'd to it; the Deſcription of both which, take as follows. *Vid. Fig.* 5. *Tab. ſeq.*

It is compoſed of a Tube ſet in Braſs, of about eight Inches long, and ſeven or eight Lines Diameter, which is left open in the Middle, for ſeeing the Bubble of Air at top.

It is carried upon a very ſtrong ſtrait Rule, about a Foot long; at the Ends of which are placed two Sights, exactly of the ſame Heighth, and like that of N° 3, which has a ſquare Hole therein, having two Fillets of Braſs very finely filed, croſſing one another at Right Angles, in the middle of which Fillets is drilled a little Hole.

There is faſten'd a little thin Piece of Braſs to this Sight, with a ſmall headed Rivet, to ſtop the ſaid Square's opening when there is Occaſion, and having a little Hole drill'd through it, anſwering to that which is in the Middle of the Fillets. The Braſs Tube is faſten'd upon the Rule by Means of two Screws, one of which, mark'd 4, ſerves to raiſe or depreſs the Tube at Pleaſure, for placing it level, and making it agree with the Sights.

The Top of the Ball and Socket is rivetted to a little Rule that ſprings, one of whoſe Ends is faſten'd with two Screws to a great Rule, and at the other End there is a Screw mark'd 5, ſerving for the Raiſing or Depreſſion of the whole Inſtrument, which is nearly level.

The Manner of adjuſting this *Level* is eaſy; for you need but place it upon its Foot, ſo that the Bubble of Air may be exactly in the Middle of the Tube, then ſhutting the Sight next the Eye, and opening the other, the Point of the Object which is cut by the Horizontal Fillet is level with the Eye. And to know whether the *Air-Level* agrees well with the Sights, you muſt turn the Inſtrument quite about, and ſhut the Sight which before was open'd, and open the other; then looking through the little Hole, if the ſame Point of the Object before obſerv'd be cut by the Horizontal Fillet, it is a Sign that the *Level* is juſt; but if there be found any Difference, the Tube muſt be rais'd or depreſs'd by Means of the Screw N°. 4, till the Sights agree with the *Level*, that is, that looking at an Object, the Bubble of Air being in the Middle, and afterwards turning the Inſtrument about, the ſame Object may be ſeen.

The *Air-Level* B is a very ſtrait Glaſs Tube, everywhere of the ſame Thickneſs, of an undetermined Length, and of a Thickneſs proportionable, being filled to a Drop with Spirit of Wine, or other Liquor, not ſubject to freeze. The Ends of the Tubes are hermetically ſealed that is, the End through which the Spirit of Wine is pour'd muſt afterwards be clos'd, by heating it with the Flame of a Lamp, blown through a little Braſs Tube to make the Heat the greater; and then, when the Glaſs is become ſoft, the End muſt be clos'd up.

When this Inſtrument is perfectly level, the Bubble of Air will fix it ſelf juſt in the Middle; and when it is not level, the Bubble of Air will riſe to the Top.

The

The *Level* D is a little Glaſs Tube, incloſed within another made of Braſs, faſten'd upon a Rule perfectly equal in Thickneſs, and ſerves to know whether the Plane be a *Level*, or no.

The next *Level*, I ſhall produce, is a Teleſcope *Air-Level*, *Vid. Fig.* 6. *Tab. ſeq.* which is alſo an Invention of the famous *French* Inſtrument-Maker *Le Bion*, and is of great Uſe in diſcovering Objects at a great Diſtance. The Teleſcope is in a little Braſs Tube, about fifteen Inches long, faſten'd upon the ſame Rule as the *Level*, which ought to be of a good Thickneſs, and very ſtraight.

At the End of the Tube of the Teleſcope mark'd 1, enters the little Tube 1, carrying the Eye-Glaſs, and a human Hair, horizontally plac'd, in the Focus of the Object-Glaſs 2; this little Tube may be drawn out, or puſh'd into the great one, for adjuſting the Teleſcope to different Sights; and at the other End of the Teleſcope is placed the Object-Glaſs, whoſe Conſtruction is the ſame as that beforementioned, belonging to the Semicircle.

The whole Body of the Teleſcope is faſten'd to the Rule, as well as the *Level*, with Screws, upon two little ſquare Plates, ſolder'd towards the Ends of each Tube, which ought to be perfectly equal in Thickneſs. The Screw 3 is for raiſing or lowering the little Fork carrying the human Hair, and making it agree with the Bubble of Air, when the Inſtrument is level; and the Screw 4 is for making the Bubble of Air agree with the Teleſcope. Underneath the Rule is alſo a Braſs Plate, with Springs to it, having a Ball and Socket faſten'd thereto.

The *Level* E places itſelf, and is compos'd of a pretty thick Braſs Rule, about one Foot long, and an Inch broad, having two Sights, of the ſame Height, placed at the Ends of the Rule; and in the midſt there is a kind of a Beam, (almoſt like thoſe of common Scales,) for ſuſpending the *Level* freely.

At the Bottom of the ſaid Rule is ſcrew'd on a Piece of Braſs, likewiſe carrying a pretty heavy Ball of Braſs. All the Exactneſs of this Inſtrument conſiſts in a perfect Equilibrium; to know which, is eaſy: For holding the Inſtrument ſuſpended by its Ring, and having eſpied ſome Object through the Sights, you need but turn the Inſtrument about, and obſerve whether the aforeſaid Object appears of the ſame Height through the Sights; and if it does, the Inſtrument is perfectly in Equilibrio; but if the Object appears a little higher or lower, you may remedy it, by removing the Piece of Braſs, carrying the Ball exactly in the Middle of the Point of Suſpenſion, and then it muſt be fix'd with a Screw, becauſe, by Experience, it was found the Inſtrument was level.

The next *Level* I ſhall produce from this *French* Author, is ſaid by him, to be the Contrivance of that truly ingenious and great Man, Monſieur *Hugens*, whoſe Name and Memory has been ſo long celebrated in the learned World. *Vid. Fig. 7. Tab. ſeq.*

It is a Teleſcope of about fifteen or eighteen Inches long, being in the Form of a Cylinder, and going through a Ferril, in which it is faſten'd by the Middle. This Ferril has two flat Branches b, b, one above, and the other below, about a fourth Part of the Teleſcope in Length. At the Ends of theſe two Branches, are faſten'd little moving Pieces, which carry two Rings, by one of which the Teleſcope is ſuſpended to a Hook, at the End of the Screw 3; and by the other a pretty heavy Weight is ſuſpended, in order to keep the Teleſcope in *Equilibrio*. This Weight hangs in the Box 5, which is almoſt fill'd with Lin-ſeed Oil, Oil of Walnuts, or any Thing elſe which will not coagulate, for the more aptly ſetting the Balances of the Weight and Teleſcope.

This Inſtrument carries ſometimes two Teleſcopes, cloſe and very parallel to each other, the Eye-Glaſs of one being on one Side, and the Eye-Glaſs of the other being on the oppoſite Side, that ſo one may ſee on both Sides, without turning the *Level*. If the Tube of the Teleſcope, being ſuſpended, be not found level, as it will often happen, put a Ferril or Ring, mark'd 4, upon it, which may be ſlid along the Tube, for placing it level, and keeping it ſo; and this muſt be if there be two Teleſcopes. It muſt be noted, that there is a human Hair, horizontally ſtrained, and faſten'd to a little Fork, in the Focus of the Object-Glaſs of each Teleſcope, which may be rais'd or depreſs'd, by Means of a little Screw, as has been already mentioned.

For proving this *Level*, having ſuſpended it by one of the Branches, obſerve ſome diſtant Object through the Teleſcope, with the Weight not hung on, and very exactly mark the Point of the Object cut by the Hair of the Teleſcope; then hanging the Weight on, if the horizontal Hair anſwers the ſame Point of the ſaid Object, it is a Sign that the Center of the Gravity of the Teleſcope and Weight, is preciſely in a right Line, joining the two Points of Suſpenſion, which continued, would paſs through the Center of the Earth.

But if it otherwiſe happens, you muſt remedy it by ſliding the little Ring backwards or forwards. Having thus adjuſted the Teleſcope, that the ſame Point of an Object be ſeen, as well before the Weight is hung on, as afterwards, you muſt turn it upſide down, by ſuſpending it to the Branch which was lowermoſt, and hanging the Weight upon the other; then if the Hair in the Teleſcope cuts the

the aforeſaid Point of the Object, it is manifeſt, that that Point of the Object is in the Horizontal Plane with the Center of the Tube of the Teleſcope; but if the Hair does not cut that Point of the Object, it muſt be rais'd or lower'd, by Means of the Screw, till it does. *Note*, You muſt every now and then prove this Inſtrument, for Fear leaſt ſome Alteration has happened thereto.

THE Hook on which this Inſtrument is hung, is fix'd to a flat wooden Croſs, at the End of each Arm of which there is a Hook, ſerving to keep the Teleſcope from too much Agitation when the Inſtrument is uſing, and for keeping it ſteady when it is carrying, in lowering the Teleſcope, by Means of the Screw 3, which carries it.

THERE is apply'd to the ſaid flat Croſs another hollowed Croſs, faſten'd with Hooks, which ſerves as a Caſe to the Inſtrument. But note, the two Ends of the Croſs are left open, that ſo the Teleſcope being covered from Wind and Rain, may be always in a Condition to uſe.

THE Foot ſupporting the Inſtrument is a round Braſs Plate, ſomething concave, to which is faſten'd three Braſs Ferrils, moveable by Means of Joints, where are Staves of a convenient Length put; the Box at the Bottom of the *Level* is plac'd upon this Plate, and may be any Ways turn'd, ſo that the Weight, which ought to be Braſs, may have a free Motion in the Box, which muſt be ſhut by Means of a Screw, ſo that the Oil may be preſerv'd in Journeys.

FIG. 8. *Tab. ſeq.* is the Repreſentation of one of the beſt Kind of *Spirit-Levels* I know of, eſpecially for the Uſe of Gardeners, if improv'd in the Manner I have there deſcrib'd. The firſt that ever I ſaw of this Kind, was in the Hands of Mr. *Bridgeman*, now deſervedly advanc'd to be one of His Majeſty's Gardeners.

IT may be made from two Foot, to two Foot and a half, or three Foot long, of any ſeaſon'd Piece of Oak, or other Wood, about three Inches wide, having Sights framed on at a a. In the Middle at X there is (according to my Deſign) a Pin, on which the Rule b b turns; and round the Center is a Convex-Glaſs, with Circles drawn round it, as on the Plan, which Circles are ſo exactly level, that whenever the frigid Liquor which is put in ſtands to a true Level, it touches one or other of theſe Circles, or ſo near to it, that you may diſcover when the Inſtrument is level. To make this more perfect, I have added a Tube at each End, which runs towards the Sights, as in other *Spirit-Levels*, which Tube is alſo join'd croſs-ways to the Convex-Glaſs, and ſhews when the *Level* is right that Way; ſo that having taken your View one Way, you may, by the Help of the croſs Rule b b, take any other *Level*, whether diagonal, ſquare, or

otherwiſe, without moving your Inſtrument again, or altering the firſt *Level.*

On the Edges of the Circle, you may have Degrees divided (if you pleaſe) according to the Degrees of a Circle, which will be of Uſe to any Gardener likewiſe in the ſetting out his Walks, and taking of Levels, and is, in ſhort, ſo univerſal an Inſtrument for his Uſe, that (if well made) I can't think any equal to it.

A Box and Needle may be alſo fix'd to it at the *Fleur-de-Lis*; and the Whole, if it falls into the Hands of one Artiſt, may be made of the greateſt Uſe. All this may be done on a plain Table.

For the Rectification of all Levels, (that I may explain myſelf the better,) take the following Account, as I find it in *Le Bion*, *Vid. Fig.* 10. *Tab. ſeq.* Plant your two Staves at A B, about fifty Toiſes Diſtance from each other, becauſe of the Roundneſs of the Earth you muſt not exceed that; then eſpying from the Station A the Point B, the Level being plac'd horizontally, and the Bubble of Air being in the Middle of the Tube, you muſt raiſe or lower a Piece of Paſte-Board or Vane upon the Staff B, (in the Middle of which, as *Vid.* B. *Fig.* 12. *Tab. ſeq.* there is an Horizontal Line,) till the viſual Ray of the Obſerver's Eye meets the ſaid Line; after which fix another Piece of Paſte-Board to another Staff of the ſame Diviſion, which we call A, the Middle of which let be the Height of the Center of the Paſte-Board; and the Level being horizontally plac'd for obſerving the Vane or Paſte-Board A; if then the viſual Ray cuts the Middle of the Piece of Paſte-Board, it is a Sign that the Level is very juſt; but if the viſual Ray falls above or below, as in the Point C, you muſt, by always keeping the Eye at the ſame Height, lower the Teleſcope, or the Sight, till the Middle of the viſual Ray falls upon the Middle of the Difference, as in D; and the Teleſcope thus remaining, the Tube of the Level muſt be adjuſted, till the Bubble, either of Air, Quick-ſilver, or Spirit of Wine, fixes in the Middle; which is done by Means of a Screw fix'd at the Bottom of all Levels, for that Purpoſe. Again return to the Staff A, and place the Level to the Height of the Point D; and looking at the Vane or Paſte-Board B, if the viſual Rays fall on the Middle of the Piece of Paſte-Board, it is a Sign the Teleſcope or Sight agrees with the Level; if not, the ſame Operations muſt be repeated, until the viſual Rays fall upon the Centers of the two Pieces of Paſte-Board. And thus, with what is ſet down in other Places, you have full Inſtructions for rectifying any Inſtrument.

The next, and which is, I think, a very genteel and ingenious Inſtrument, is the Teleſcope *Spirit-Level:* The Invention, as

as I take it, (for I am not, as yet, well acquainted with that Gentleman,) of *William Siſſon*, at the Corner of *Beauford-Buildings*, in the *Strand*, being of great Uſe for thoſe who are to take the Dependance of a River, (or any other long Length,) for Navigation, or otherwiſe, be it fifteen or ſixteen Miles, or ſometimes more.

This Inſtrument conſiſts of a Braſs Teleſcope, of a convenient Length, the longer the better, provided, the Parts of the Inſtrument, which ſupport it, be proportionably ſtrong. Within this Teleſcope is fix'd a Hair, and a ſmall Micrometer, whereby the Diſtances may be determined at one Station near enough for the Buſineſs of Levelling; upon this Teleſcope is fix'd, with two ſmall Screws, the Spirit Tube, and Bubble therein, which Bubble will reſt exactly in the Middle of the Tube, when the Teleſcope is ſet truly level.

Under the Teleſcope is a double Spring, with two Screws, by which the Bubble is brought exactly to a Mark in the middle of the Tube; to which Spring is fix'd a Conical Ferril, which is a Direction for the Teleſcope to move horizontally at Pleaſure. There is alſo a three-legged Staff, a Ball, Socket, and four Screws, to adjuſt the Horizontal Motion, the ſame with that belonging to all ſurveying Inſtruments.

For your Aſſiſtance to this, and the other Levels before mentioned, you are to provide two Station Staves, (for one whereof *See Fig.* 12. *Tab. ſeq.*) each ten Foot long, that may ſlide one by the Side of the other, to five Foot, for eaſier Carriage; let them be divided into 1000 equal Parts, and number'd at every tenth Diviſion, 10, 20, 30, 40, &c. to 100, and from 100, 110, 120, &c. to 200, and ſo on till you come to 1000; but every Centeſſimal Diviſion, (which is the moſt as can be expreſs'd in the Figure before mentioned,) as 100, 200, 300, &c. to 1000, ought to be expreſs'd in large Figures, that the Diviſion may be more eaſily counted; and you may have another Piece five Foot long, divided alſo into 500 equal Parts, to be added to the former, when there ſhall be Occaſion.

Upon theſe Staves are two Vanes, or black Boards, made to ſlide up and down, which will alſo ſtand againſt any Diviſion on the Staff, by the Help of Springs; theſe Vanes are beſt made thirty Parts wide, and ninety Parts long; let the Faces of them be divided into three equal Spaces, by two Lines drawn Length-ways; let the two extream Parts be painted white, and the other two black, which will render them fit for all Diſtances.

Being thus provided with a good Inſtrument, two Station Staves, a Chain, and two Aſſiſtants, you may proceed to your Work; but

firſt

firſt it will be neceſſary to know if your Inſtrument be well adjuſted.

Now to do this, you are to chuſe ſome Field or Meadow, which is nearly level, and ſet down the Inſtrument about the Middle thereof, and make a Hole in the Ground, under the Center of the Inſtrument; from which meaſure out a right Line, ſome convenient Length, as twenty Chains, and there leave one of your Aſſiſtants with his Station-Staff; and then return to the Inſtrument, and meaſure out the ſame Number of Chains, *viz.* twenty, the other Way, by the Direction of the Inſtrument and laſt Station-Staff, as near in a right Line as you can gueſs, and there leave your other Aſſiſtant with his Station-Staff; ſo will the Inſtrument and two Station-Staves be in the ſame Line.

Then return to the Inſtrument, and ſet it Horizontal, which is preſently done by the Ball and Socket, and turn the Teleſcope about on its Horizontal Motion to your firſt Aſſiſtant, and move the Teleſcope by the two Screws in the double Spring, till the Bubble reſts exactly in the middle of the Spirit-Tube; then obſerve where the Hair cuts the Staff, and direct your Aſſiſtant to move or ſlip the Vane or Board up or down, till the Hair cuts the Middle thereof, ſo that you may ſee as much of the Vane above the Hair as below it, and there give him a Sign to fix it; then direct the Teleſcope towards your ſecond Aſſiſtant, and proceed in the ſame Manner; ſo are the Vanes on each Staff equidiſtant from the Center of the Earth.

Remove the Inſtrument to that Aſſiſtant which is neareſt the Sun, if it ſhines, that you may have the Advantage of its Rays upon the other Aſſiſtant's Vane, and there ſet down the Inſtrument as near the Staff as you can; then having ſet the Inſtrument Horizontal, ſo that the Bubble reſts in the middle of the Tube, obſerve what Direction is then cut by the Hair in the Teleſcope, above or below the middle of the flat Board or Vane; for ſo many Diviſions muſt the other Aſſiſtant's Vane be elevated, or depreſs'd, which you muſt direct him to do accordingly.

Here the Diſtance of the Inſtrument, from the Station-Staff, is forty Chains, for which you muſt make an Allowance for the Earth's Curvature, which, by the Table, which will be produc'd in one of the next Pages, you will find to be 16 $\frac{6}{10}$ Parts, therefore let the Vane on the Staff be rais'd 16 $\frac{6}{10}$ Parts.

Now direct the Teleſcope to the Vane thus rais'd, and if the Hair cuts the Middle thereof, whilſt the Bubble reſts in the Middle of the Tube, the Inſtrument is right; but if not, then you muſt raiſe

raiſe or depreſs the Teleſcope by the Screws in the double Spring, till the Hair cuts the Middle of the Vane; and then, by the Help of the Screws that fix'd the Tube to the Teleſcope, move the Bubble till it reſts in the Middle of the Tube; ſo is the Level adjuſted.

As to the Allowances to be made for the Curvature of the Earth, when the Station-Staves are planted at unequal Diſtances from the Inſtrument, you muſt take the following Method:

Suppose the Inſtrument was plac'd on an Eminence, between the two Valleys a and b, *Fig.* 11. *Tab. ſeq.* and the firſt Aſſiſtant ſtanding with his Station at c, and the ſecond at d, and it is required to know the different Height of the Hills c and d.

First ſet the Inſtrument Horizontal; and then direct the Teleſcope to the firſt Aſſiſtant's Staff at c, and by the Spring-Screws ſet the Bubble exact, obſerving where the Hair cuts the Staff, and by Signs cauſe him to move the Vane higher or lower; till the Hair cuts the Middle thereof; and then give him a Sign to note down the Diviſion cut by the upper Edge of the Vane, which ſuppoſe 104 Parts from the Ground, and by the Micrometer in the Teleſcope, I find the Diſtance, from the Inſtrument to the Staff at c, to be about ten Chains.

Then I direct the Teleſcope to d, and proceed in the ſame Manner as before, and find that the Hair cuts 849 Parts from the Ground, and by the Micrometer the Diſtance to d, is determin'd to be about thirty five Chains.

Next I look into the Table of Curvature following, and find againſt ten Chains, one Part to be deducted for the Curvature of the Earth at that Diſtance, ſo will the Aſſiſtant's Note be made 103 Parts.

Also againſt thirty five Chains, I find $\frac{7}{1210}$, which being deducted out of 849, there remains $836\frac{3}{10}$ Parts which muſt be noted by the ſecond Aſſiſtant.

Now if 103, as noted by the firſt Aſſiſtant be ſubſtracted from $836\frac{3}{10}$, as noted by the ſecond, the Remainder will be $733\frac{3}{10}$, and ſo much the Hill c is higher than the Hill d.

If the Spring-Head, or Conduit-houſe Q, be on the Precipice of a Hill, you muſt make a very ſhort Level H to F, by a very tall Pole plac'd at c, which Pole let remain till you have mov'd your Inſtrument to R, at which Time you may turn your View backwards and forwards both to G and D. But to proceed:

Here

Here follows a Table of the Earth's Curvature, calculated to the Thoufandth Part of a Foot, at the End of every Chain, from one Chain to forty.

Chains.	Dec. feet.	Chains.	Dec. feet.	Chains.	Dec. feet	Chains.	Dec. feet.
1	000	11	013	21	046	31	099
2	000	12	015	22	050	32	106
3	001	13	017	23	055	33	113
4	002	14	020	24	060	34	120
5	003	15	023	25	065	35	127
6	004	16	026	26	070	36	134
7	005	17	030	27	075	37	141
8	007	18	033	28	081	38	149
9	008	19	037	29	087	39	157
10	010	20	041	30	093	40	166

THUS you have a Table of the Curvature of the Earth; but if the Table is not at hand, or the Number requir'd be not to be found therein, then you may find the Allowance which is to be made at any Diftance, by the following Rule:

MULTIPLY the Square of the Diftance in Chains by 31, and divide the Product by 300000, you will have the Anfwer.

IN this Manner making Allowance for the Curvature of the Earth, you may fend a Station-Staff forwards half a Mile, or farther from the Inftrument, and take a Sight over Valleys at once, the Horizontal Diftance being, in this Cafe, the only Thing to be regarded.

THUS much of the general Ufes of the Levelling Inftruments before mentioned, Curvature of the Earth, *&c.* But before I proceed to that which is more particular, I mean the Operation it felf, the Method of noting down in the Field fuch Obfervations as fhall occur, (according to my Promife,) I fhall give an Account of a very extraordinary Inftrument, contriv'd by Mr. *Thomas Heath*, Mathematical Inftrument-Maker, next Door to the *Fountain-Tavern* in the *Strand*, a Perfon who, for Curioufnefs of Invention and Workmanfhip, (being himfelf a through Mathematician,) equals, if not excels, any of his Profeffion.

THIS

THIS Inſtrument conſiſts of a Braſs Circle or Limb AA, *Vid. Tab. ſeq.* ten Inches in Diameter, or any other Size at Pleaſure, divided into 360 Degrees, and an Arch of it is divided into Parts, figured each Way ten, twenty, thirty, *&c.* to ninety, being mark'd Feet, and are for taking the Perſpective of a Building, upon which are two fixed Sights b b, for viewing Objects that are near, or when the Inſtrument is uſing in hazy Weather, when they cannot be diſtinctly ſeen through a Teleſcope. This Limb is fix'd upon a Braſs Pillar or Cylinder, having a Ball at the Bottom of it, that goes into a Socket made in the Middle of the round Plate G G, ſo that by Means of the Ball and Socket: The Plan of the Limb A A may be ſet to a requir'd Poſition or Inclination, with reſpect to the Plane of the Circle G G, and may be kept to that Poſition by Means of a Screw and Worm underneath the Plate G G; the circular Plate B B is fixed upon the aforeſaid Pillar or Neck of the Ball, having its Plane parallel to the Plane of the Limb A A, and has four Screws in it; the Worms of which preſſing againſt the circular Plate G G, are for ſetting the Plane of the Limb A A level or parallel to the Horizon, by Means of a little Spirit Air-Level f f, fixed to the Top of the Teleſcope E E, that ſo the Inſtrument may ſerve as a Quadrant, in taking the Quantity of Degrees of an Altitude, and likewiſe for other Uſes hereafter mentioned. The Plate a a a a, called the Index, is moveable about the Centre of the Limb A A, and the Arches of the two oppoſite Pieces of it, or Ends of the Index, reſt upon the Limb, in order to take the Quantity of Degrees of an Angle, contain each thirteen Degrees of the Limb; which Arches are each divided into twelve Parts, and figur'd 10, 20, 30, 40, 50, 60, that ſo the Quantity of an Angle may be taken to 5 Minutes. This Index has a Box and Needle c c fixed upon it, and near the aforeſaid Ends of the Index, are plac'd perpendicularly two ſimilar and equal vertical Arches c c, c c, of about thirty nine Degrees each, which are joined to the croſs Piece D D ſupporting the Centre, about which a Teleſcope E E moves. This Teleſcope carries four perpendicular or vertical Sights e, e, e, e, for viewing Objects in hazy Weather, or that are near; as likewiſe two Pieces upon the Arches c c, c c, ſerving as an Index; which Pieces each contain an Arch of thirteen Degrees of the Arches c c, c c, being each divided as the Ends of the Index a a a a were, that ſo the Quantity of an Angle of Altitude may be taken to five Minutes. Theſe Arches c c, c c, contain three Scales of concentrick Diviſions, mark'd *De*, *Li*, *Fe*, the firſt being Degrees, the ſecond Links, and the third Feet, the former giving by the Thread of the Middle of the Index the Degrees of the

Altitude or Depreſſion of an Object, if not exceeding thirty nine; the other the Number of Links in every Chain's Length, at that Angle of Altitude or Depreſſion that are to be taken from, or added to the Hypothenuſal Line of one Chain, in order to have the horizontal Line, by which Means the horizontal Line of an Hill will be very exactly obtained; and, laſtly, the third, the Height or Depth of an Object in Feet, when the Inſtrument ſtands at 100 Feet Diſtance from it.

At the Letter p there is a little Pin faſten'd to the Teleſcope, which is for keeping the Teleſcope and Index ſuch, that its Line of Collimation be parallel to the Plane of the Limb.

Finally, the three Legs of the Inſtrument ſcrew into three Braſs Pieces, which conſtitute a Triangle, and are faſten'd underneath the circular Plate G G, and open and ſhut at Pleaſure, and may be unſcrew'd in the Middle, that ſo their Length being diminiſh'd by one half, they are render'd more portable.

N. B. The Centre, about which the Index a a a a moves, and upon which the Needle hangs, is fix'd to the Plate A A, that ſo when the Index is moving, the Needle is not thereby diſturbed.

This general and moſt curious Inſtrument of Mr. *Heath*'s (with others before mentioned) being thus deſcrib'd, let us now come to the Operation it ſelf, in which it is requir'd to know whether Water may be convey'd in Pipes or Trenches from a Spring-head to any determin'd Place.

At the Spring-head ſet up one of your two Station-Staves, as nearly perpendicular as you can, and leave with one (whom you may call your firſt Aſſiſtant) proper Directions for raiſing or depreſſing the Vane on his Staff, according to certain Signs which you (ſtanding at your Inſtrument) ſhall give him. Alſo let him be provided with Pen, Ink, and Paper, to note down very carefully the Diviſion of the Staff which the Vane ſhall cut when you make a Sign that it ſtands in its right Poſition.

Carry your Inſtrument toward the determined Place you are going to, as far as you can ſee, ſo that through the Teleſcope you may but ſee any Part of the Staff left behind when the Inſtrument is ſet horizontal; and from that Place ſend your ſecond Aſſiſtant forward with his Station-Staff, with the ſame Inſtructions which you gave your firſt.

Set the Inſtrument horizontal, by the Help of the Ball, Socket, and Screws; and direct the Teleſcope to your firſt Aſſiſtant's Staff, and then by the help of the Spring-Screws bring the Bubble exactly to the Middle of the Tube, and when it reſts there give a Sign for your Aſſiſtant to note the Parts of the Staff.

Now

TURN about the Teleſcope to your ſecond Aſſiſtant's Staff, and by the Spring-Screws, as before, ſet the Bubble exact; then direct your ſecond Aſſiſtant to move the Vane higher or lower, till you ſee the Hair in the Teleſcope cuts the Middle of the Vane or Sight-Board, (but in long Diſtances the Hair will almoſt cover the Vane, however, let it be ſet in ſuch a Manner that as much may be above the Hair as below it, as near as you can gueſs,) and then give him a Sign to note the Diviſion on the Staff; and always let your Aſſiſtants note the Diviſion cut by the upper Edge of the Vane.

LET your firſt Aſſiſtant then bring his Station-Staff from the Spring-head, and changing Places with the ſecond Aſſiſtant, let your ſecond Aſſiſtant carry his forwards to the determin'd Place to which you are going, and at a convenient Diſtance erect it perpendicular, whilſt your firſt Aſſiſtant tarries with his Staff where your ſecond Aſſiſtant ſtood before.

PLACE your Inſtrument between your two Aſſiſtants, as near the Middle as you can, (on Account of the Curvature of the Earth,) and firſt direct your Teleſcope to your firſt Aſſiſtant's Staff, and when the Teleſcope is levell'd to one of the Diviſions on the Staff, let him note that Diviſion in an orderly Manner under the firſt Obſervation; and let the ſecond Aſſiſtant do the ſame. And in this Manner proceed over Hill and Dale, as ſtrait forwards as the Way will permit, to the appointed Place, (only repeating thoſe Directions,) though it be twenty Miles Diſtance from the Spring-head. But in your whole Paſſage let this be a conſtant Rule, from which you muſt never depart, *viz.* that your firſt Aſſiſtant muſt at every Station ſtand between the Spring-head and your Inſtrument, and your ſecond Aſſiſtant muſt always ſtand between the Inſtrument and the appointed Place to which the Water is to be convey'd; and alſo the firſt Aſſiſtant muſt be ſure to place his Staff exactly in the Place where the ſecond ſtood.

BEING come to the Place appointed, let both your Aſſiſtants give in their Notes, which ought to ſtand in Manner and Form following:

will not be able to ſee any Part of the Staff when the Inſtrument is ſet horizontal,) which might as well be done alone, (as in the foregoing Obſervations,) in the Manner deſcrib'd in the Table of Curvatures.

In the Beginning of this Chapter, Mention was made of an old plain Water-Level, us'd by our Water Meadow-Men, ſome Account of which, (or very near it,) I remember to have ſeen in the Beginning of *Blythe*'s Husbandry, which Inſtrument, and its Uſes, in making Trenches, I would recommend before any other yet named, if you can keep a little out of the Wind. *Vid. Fig.* 13. *Tab. ſeq.*

Let A B be the Section of a new Cut, made for the conducting of Water to any Place, and C C D the Top of the Level, which has two Sights fram'd on, as f, g, and two Iron Rods, as h, i, going through the Middle of the Level near C and D, which are ſo put in, that they will eaſily admit of the Levels riſing or ſinking, by either of the Screws K, L.

This Level (being of the dryeſt Oak, three Inches ſquare) ought to be ſix or eight Foot at leaſt in Length, (the longer the better) in the middle of the Top of which let there be a Channel or Trough made, ſuch as is us'd to be for Chickens to eat their Meat out of, and as is deſcrib'd in *Fig.* 14. *Plate* 3. about an Inch, or an Inch and Quarter over, having at each End a ſquare Well, into which the Water ſhall fall, whereby its Level may be the more conſpicuous and plain. And with this we did my Lord *Coningsby*'s Trench to a very great Truth.

CHAP. VII.

Of the proper Methods to be taken in the adjuſting the Levels or Falls from a Spring-Head, ſo as to conduct them by a gradual Deſcent to the Houſe, or other Place required.

THE Deſcent from the Spring-head to the Reſervoir being taken, as directed in the laſt Chapter, the next Thing to be done is the determining what Fall the Water is to have, or, in other Words, how many Feet or Inches, or how much Dependance is to be allowed to a Yard, to a Pole, or to a hundred Feet or Yards, or a Mile or Miles, in Proportion, ſo as that the Water may have a proper Current, and may at laſt not fall too low, but be brought gradually to the Top of the Reſervoir or Pond, where it is to be uſed.

But

Yet before we proceed far into this neceſſary Adjuſtment of the Dependance or Fall of Water, it will not be improper to enquire into the Fall of ſome Aqueducts and Water-Courſes, both at Home and Abroad, ſince 'tis from Fact rather than from Theory and Speculation we muſt deduce the moſt certain Conſequences in this or any other Employ.

Vitruvius, *Lib.* 8. *Cap.* 6. as hinted at in the laſt Chapter, writes, " That the *Romans* allow'd for the Channels or Sewers of their " Aqueducts, for every Hundred Foot, running half a Foot of " Declination or Sloping, (which is near Twenty ſeven Foot " in a Mile, and if any Hills were in their Way, they dug " through them, making Vents to give Air at convenient Diſtances, " not being appriz'd in that early Dawn of Hydroſtaticks, that if you " would confine your Spring in Leaden Pipes, it would (as the Re- " verend Dr. *Deſaguliers*, in his *Elements of Natural Philoſophy*, has " it) riſe over Hill and Dale, if the Spring-head were ſo high as to " over-top them, proper Allowance being made for Friction, and the " Interpoſition of Air ;" which may be let out by Wind-Cocks, as ſome Authors have taught.

The ſo-much-fam'd Aqueduct of *Claudius*, as is alſo before ſet down, was (as the ever memorable Mr. *Addiſon* informs us, in his Travels into *Italy*,) five Foot and a half in a Mile, but whether that ingenious Gentleman means *Italian* or *Engliſh* Miles, does not ſo plainly appear ; but if the latter, Experience tells us it is an Allowance large enough, even though it were not to be above a Foot Fall in a Thouſand.

Varennius, in his *Geograph. General. Prop.* xxvi. *Pag.* 268. relates from ſome *French* Writers, That the *Seine*, out of which the Water is carried from the Armory at *Paris* to the Royal Garden, is ſcarce one Foot Fall in Five Hundred Fathom, every Fathom being ſix Foot; now 500 being multiply'd by ſix, the Produce is 3000 Foot, which is half a Mile, and 260 Foot if accounted in the *Engliſh* Way, by which it appears, that that Fall is about two Foot in a Mile: But later Experience tells us, that Water will deſcend in leſs than that.

The Water-Courſe at *Plymouth* is, as I am inform'd, but five Inches in a Mile Fall ; and that which I made ſome Years ſince for the Earl of *Coningsby*, is about four. The new River, as I am inform'd by my ingenious Acquaintance Mr. *Mills*, now chief Surveyor of that Work, who took it at ſeveral Places with great Care, is, in the Mean, but between three or four Inches Fall in a Mile ; though in ſome Places it is more, others leſs: And I remember to have read

ſome time ſince in ſome of Sir *Jonas Moore*'s Works, that he allow'd but three Inches; and the ſame is practis'd in the Fenns of *Lincoln* and *Cambridge* Shires, where the Water is almoſt on a deadiſh Flat; but the general Allowance is four Inches and a half by all Ingineers.

To conclude this, The conducting of Water varies according to the Conveyances in which you carry it. Water conveyed in Pipes, eſpecially if they are ſmall, requires more Dependance than any other Way, on the Account of the Friction that there is againſt the Sides of the Pipes, as well as the Wind-boundedneſs that is generally therein, of which more is ſaid elſewhere. That which is convey'd in Drains, will paſs more eaſily and free; but Water paſſing in an open Carriage, will paſs the freeſt of all, except the Winds are againſt the Stream, becauſe of that continual Agitation and Impulſe that there is in the Air. But of this more in another Place.

But to come to Practice: Suppoſe that the Length you are to convey the Water is 1000 Yards, and the Fall from the Spring-head to the Reſervoir or Houſe is twenty five Foot nine Inches, and it ſhould be required to know how many Inches, or Parts of an Inch, muſt be given to every Yard or Pole, in order to give this Water its proper and gradual Deſcent or Fall.

In the firſt Place, you are to turn the twenty five Foot nine Inches into Inches, which makes 309; but that not being reduc'd into Terms low enough to be divided, divide by the 1000, the 309 muſt be again multiply'd by 12, to bring it into Lines or Parts of an Inch, the Produce of which is 3708, as is ſeen in the Example.

F.	In.
25	9
12	0
300	0
9	0
309	0
12	0
3708	0

Which being divided by 1000, the Number of Yards contained in the Length, the Quotient will be three Lines $\frac{708}{1000}$ of a Line, which is near 3 Lines $\frac{3}{4}$, or a Quarter and $\frac{1}{4}$ of an Inch; however, you may give it a Quarter and half Quarter,, which is four Foot ſeven Inches in a Mile, and have to ſpare and to anſwer for any Error

Error or ſmall Miſtake that may happen in the Execution of the ſaid Work.

Suppose farther, that the Length of this Fall of twenty five Feet nine Inches, be four Miles and a Quarter, and it is requir'd to know how many Feet or Inches it is proper to allow in a Mile, or any Part or Quantity of a Mile.

First reduce the four Miles and a Quarter into Quarters of a Mile, which making nine by ſuch Multiplication, divide the twenty five Feet nine Inches by nine, and the Quotient is the Anſwer.

EXAMPLE.

	Fe.	In.
	25	9
	12	0
9)	309	0 ($34\frac{1}{3}$
	39	0
	34	3

And the Anſwer is $34\frac{1}{3}$ or 2 Foot 10 Inches $\frac{1}{3}$, and ſo much muſt be allowed for the Fall in a Quarter of a Mile, which is one Foot five Inches in a Furlong, and a little more than one Line or one twelfth of an Inch to a Pole, and eleven Foot and a half in a whole Mile a very good Dependance for the Paſſage and Conveyance of Water where it can be had.

But there are other Things to be conſidered, in relation to the Conveyance of Water in Pipes, I mean thoſe of Friction, Wind-boundedneſs, &c. becauſe as *Marriot* and his Reverend Tranſlator obſerve, (and that from curious Experiments,) that Water never riſes to its own Level, on Account of the Friction that is on the Sides of the Pipes, which Friction increaſes the longer the Diſtance is.

Now to adjuſt this Stoppage or Friction as near as may be, the general Rule amongſt Workmen is to allow one Eighth of the Height for the Interruption or Hindrance it meets with in its long Paſſage.

So that if the Deſcent from a Spring-head to the Reſervoir be 128 Foot, you are, according to this general Rule, to divide it by eight, and the Produce will be ſixteen; which ſhews that the Water will not riſe ſo high as the Spring-head by ſixteen Foot.

But Monſieur *Marriot* (to whom ſo much is owing for his Experiments in Hydroſtaticks,) has brought this Matter to a more exact Calculation, producing it as a certain general Rule, that *the Difference of the Height in Jets*, or he might have ſaid in other Words,

the Deſcent of the Water from its Head to the Reſervoir or Place aſſigned for the Reception of it, is in a *Subduplicate Ratio of its Height*; and though 'tis certain that that ingenious Gentleman made uſe of this Rule to demonſtrate the Riſe of Jets in open Air, and as external Air has undoubtedly a greater Effect on the Riſe of Water, than the Friction againſt the Sides of the Pipes, we may be the more ſure, that if there be any Error, it is on the right Side, and that, without any great Deviation from Truth, it may be applied to the Friction, that is in encloſ'd Pipes.

But to proceed upon the Foot of the foregoing Rule, it is, as may be ſeen *Pag.* 270. of Dr. *Deſaguliers*'s Tranſlation, and which is confirm'd by undoubted Experiments, that a Spring-head five Foot one Inch high, will raiſe the Water five Foot, and that conſequently the Friction that is allow'd is one Inch ; and according to this Proportion the following Table is calculated.

A Table of the Heights to which Water will riſe, proceeding from Reſervoirs or Spring-heads of different Heights ; as alſo from five Foot to one hundred.

Height of the Reſervoir or Spring-head.		The Height to which Water will riſe.	
Feet.	Inch.	Feet.	Inch.
5	1	5	0
10	4	10	0
15	9	15	0
21	4	20	0
27	1	25	0
33	0	30	0
39	1	35	1
45	4	40	0
51	9	45	0
58	4	50	0
65	1	55	0
72	0	60	6
79	1	65	0
86	4	70	6
93	9	75	0
101	4	80	0
109	1	85	0
117	0	90	0
125	1	95	0
133	4	100	0

It

It has before been obſerved, that the Weakneſs of Water that runs a great Way, is a great deal more in Proportion to the Length it runs, than to any other Cauſe, it being found by Experiments, (as the learned and induſtrious Dr. *Deſaguliers* has it,) that this Diminution or Weakening of the Water diminiſhes rather in Proportion to the Length it runs, than to the Friction againſt the Sides of the Pipes.

But as this Diminution is Fact, (let it proceed from what Cauſe it will,) and as all Motions decreaſe in Proportion to the Spaces through which they paſs, it may not be improper, before we quit this Chapter, to endeavour at its Determination as near as poſſibly we can, that we may come the nearer to the Truth of our Calculation, in the giving this requiſite Dependance to Water that is to run from a Spring-head to the Reſervoir (as before) in Leaden or other Pipes.

And ſince this Diminution or Stoppage is (as all other Motions are) in a ſubduplicate Ratio to the reſpective Spaces through which it paſſes, let us ſuppoſe, that, as Water that falls from a Reſervoir of 133 Foot high, riſes but to 100 Foot at 1000 Yards Diſtance, and that this Diminution beginning from thence increaſes gradually, ſuppoſe four Inches at the firſt, and ſo on, according to the aforementioned *Ratio*, then the Account may ſtand thus:

A Table of the Diminution or Decreaſe of Water paſſing through Pipes of great Lengths.

Length.	Decreaſe.	
Yards.	Feet	Inch.
1000	0	4
1500	0	9
2000	1	4
2500	2	1
3000	3	0
3500	4	1
4000	5	4
4500	6	9
5000	8	4
5500	10	1
6000	12	0
6500	14	1
7000	16	4
7500	18	9
8000	21	4
8500	23	1
9000	27	0
9500	30	1
10000	33	4

By which it appears, that this Diminution will be thirty three Feet four Inches in 10000 Yards, or about five Miles and three Quarters, or ſomething more. And this ſeems to be the leaſt that can be allow'd; ſo that were we to make an exact Calculation from theſe Rules for the Deſcent of Water, the four Miles and a half in Length before mentioned, it would come to agree pretty nearly with what I have been thus endeavouring to eſtabliſh for a certain Rule, which will be viſible from the Example following, which is ſumm'd up in two Lines.

		Fe.	In.
Imprimis,	The Friction of 25 Feet 4 Inches about	2	2
Secondly,	The Diminution or Decreaſe in paſſing through 8000 Yards, which is a little more than four Miles and a half,	21	4
	In all	23	6

But notwithſtanding what has been ſaid of this * Diminution or Stoppage in Pipes of Conduct, yet in large open Aqueducts, Rivers, or Sewers, (where the Friction is not ſenſible,) there will be no Occaſion for this great Care in the Calculation of this Dependance in Water.

It is apparent from what has been before advanc'd, that one Foot in a Mile is Dependance large enough for any River, Aqueduct, or the like; it being a conſiderable Rule in Hydroſtaticks, that the larger the Aqueduct or Pipe of Conduct is, the leſs is the Friction, which may be ſo enlarg'd as not to be ſenſible at all.

These Things being premis'd, and in ſuch a plain Manner, that the Conducter of Springs may ſee if he is like to run into an Error, by attempting at that which it will be impoſſible for him to perfect by natural Means, the next Thing requir'd is the Proceeding on with the Work.

When you are to convey Water for about 1000 Yards, and have from the foregoing Rules known how much Fall it is proper to give in a Yard, as is ſet down in the Example at the Beginning of this Chapter, *viz.* a Quarter of an Inch, if you proceed by the Garden Level and ten Foot Rod, which is as good a Method as any: Let your Level be a little above ten Foot long, and exactly at the ten Foot nail on a Piece of

* What I would endeavour to eſtabliſh from theſe Rules, is, that though Water in an open Sewer or Drain may paſs at four, five, or ſix Inches in a Mile Fall, yet if it be to paſs through Pipes of Conduct you can't allow it leſs than five Foot Fall; and ſo the Aqueducts of *Rome* are, as is before obſerved. I will not poſitively ſay, that Water won't paſs at all in a leſs Allowance, becauſe I have not had Experience of it; but I will venture to ſay it will paſs freely, which is the ſame Thing.

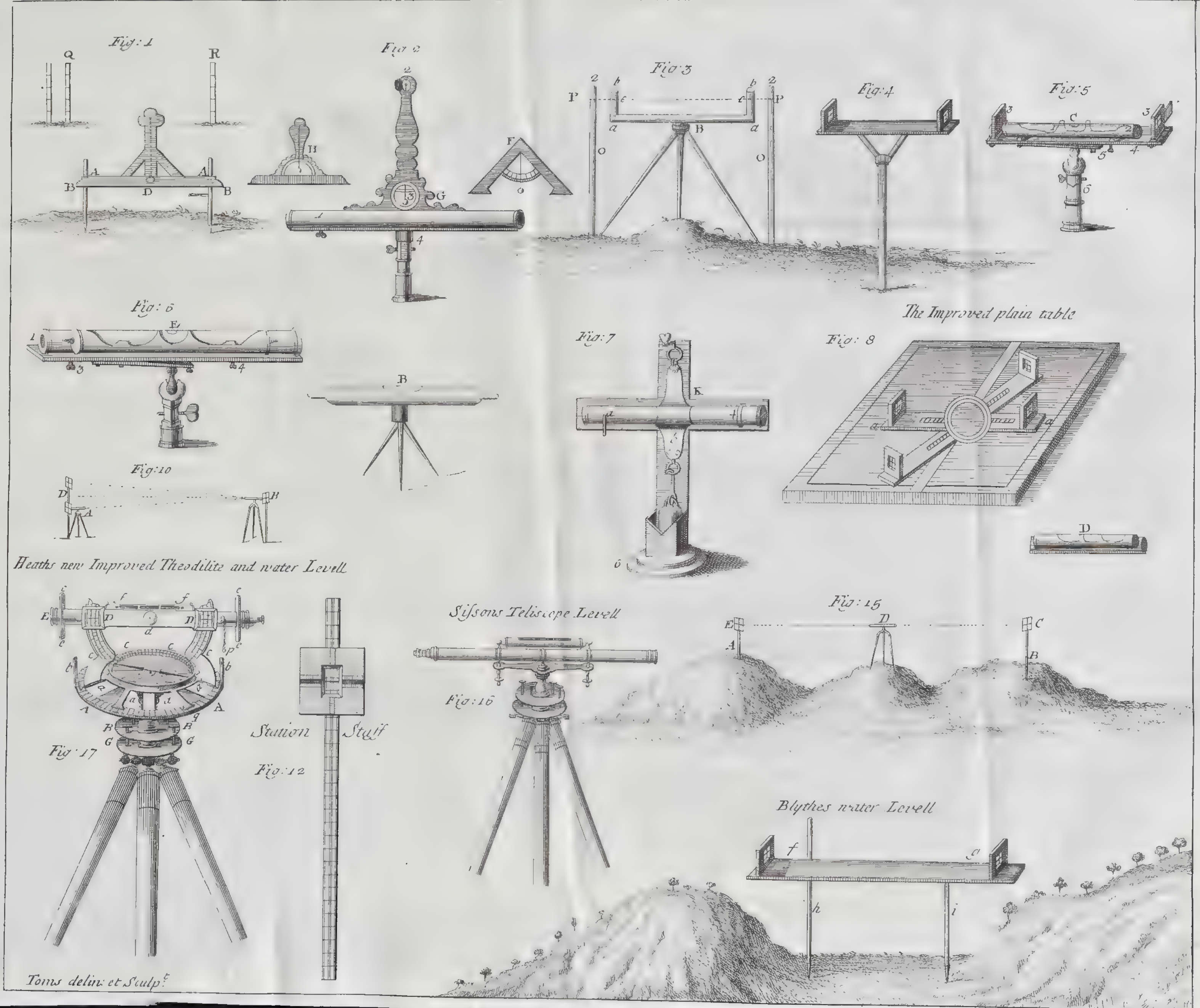


Fig: 1
Fig: 2
Fig: 3
Fig: 4
Fig: 5
Fig: 6
Fig: 7
Fig: 8
The Improved plain table
Fig: 10
Heaths new Improved Theodilite and water Levell
Sissons Teliscope Levell
Fig: 15
Fig: 16
Fig: 17
Station Staff
Fig: 12
Blythes water Levell
Toms delin: et Sculp.

‹
t
t
v
w

of Wood of $\frac{3}{4}$ $\frac{1}{3}$ of an Inch thick, and beginning about a Foot or two below the common Surface of the Spring, as it is in the higheſt and beſt Seaſons, or exactly at the Mark as it is in the loweſt, keep that End of your Level on which the Piece of Wood is nailed always from the Spring, and that will give the firſt Dependance. You may if you pleaſe turn over the Level three or four times, and drive good ſquare Stakes down ſo, as that they may remain ſome Time: And if you can ſee any great Length, you may with Boning-Staves, with which a good Workman ought always to be provided, bone quite through that View: But if you are oblig'd to go winding, then you muſt turn your Level over and over again, and your Level ſhould be ſo conducted, as that the Stakes may ſtand juſt upon the Brow of the natural Ground, that your Pipe may not lie within above three Foot of the Surface; or if it be an open Sewer, you may not break up above two or three Foot, nor dig above two or three Foot deep in all Sideling Ground.

To effect the ſame by the Water or Spirit-Level, you are to ſtand at the Spring-head, and having turn'd your Inſtrument on the hanging Level, or, in other plainer Words, on the Hang of the Hill where the Water is to paſs, let your Aſſiſtant ſet forwards with a ten Foot Pole or Rod in his Hand, and holding his Hand at about four or five Foot high, and let him move up and down the Hill till the Level exactly ſtrikes the Aſſiſtant's Hand; and if you can carry it ſtrait, let this be ſeventy, eighty, ninety, or 100 Yards, more or leſs, allowing the Quarter of an Inch to a Yard Fall, as is before ſpecify'd, which ſuppoſe to be eighty Yards, you are to allow ten Inches lower to your Gauge-Stake, and bone in new Pins or Stakes at every fifteen Foot aſunder; from which Gauge you are to dig your Cut three Foot deep to lay your Pipes in; or if it be a bank'd River or Sewer, you are to throw your Stuff in all Sideling Ground to the loweſt Side, letting this Stake be in the Middle of your Cut, be it either of fifteen or twenty Foot, either of which are ſufficient in Works of this Kind. But of this more in its proper Place.

What I have to obſerve more on this Head, is, that you creep along the Side or Precipice of the Hill, if it be for an open Sewer or Drain, to be made of Brick or Stone, and be as exact as poſſibly you can in your Level; but if your Conveyance be of Leaden, Wooden, or Earthen Pipes, and the Spring lies ſo high as that you can command any Hills that lie between it and the Houſe or Reſervoir to which you are to carry it, and can by the Rules before going be ſure you can carry the Water over them, you may go the neareſt Way. Of which more in the next Chapter.

CHAP.

CHAP. VIII.

Of the conducting of Water by Aqueducts, Drains, &c.

RUnning Water conducted in Aqueducts is certainly to be preferr'd to Water rais'd by Engines, becauſe Repairs, which hinder the coming in of Water, are not ſo often needed, and the Water may come eaſier and in greater Plenty than when it is rais'd by Engines, and is brought in by Pipes; beſides, the Expence is generally larger, both in the doing it at firſt, as well as keeping it afterwards; and perhaps it had been cheaper, as well as better, for that great King of *France*, by whoſe Magnificence the Water-Works of *Verſailes* and other Parts of *France* grew to ſuch a ſtupendous Height, to have conducted the Water from the *Eure* to the Caſtle of *Verſailes*, though it ſhould have been twenty, thirty, or forty Leagues Diſtance from that Palace, than to have been at ſo extravagant an Expence, as he was in the Machine of *Marly*, and the coſtly Aqueducts that lead therefrom to *Verſailes*; a Work ſo coſtly, that I remember to have read a ſmall Treatiſe, writ by one of his own Officers, where, though in an abſolute Monarchy, he dar'd to tax his Maſter with Profuſeneſs and Extravagancy.

MOST of the Aquaducts of *Rome*, and ſome Water-Conveyances in *England*, are not a great deal ſhort of the Diſtance that the *Eure* was from *Verſailes*; and that great Prince was ſo ſenſible of his Errors, that Monſieur *de Louvois* employ'd the Editor of Monſieur *Marriot*'s Hydroſtaticks, as he tells us in the Preface thereto, to take the Levels; and that at *Pointjoiu* ſeven Leagues above *Chartres*, the Water was higher by 110 Foot than the higheſt Ground about the Caſtle of *Verſailes*; a plain Inſtance how greatly that Prince had miſapply'd his Money.

VITRUVIUS, *Lib.* 8. *Chap.* 6. ſets down, that the Ancients, in order to the bringing of Water to Towns, Cities, *&c.* after they had taken the Level, they conducted it three ſeveral Ways, by Aqueducts, Pipes of Lead, and Pipes baked in a Potter's Furnace.

THESE Aqueducts which brought the Water to *Rome*, and of which Mention has been already made in the Introduction to this Work, and elſewhere, are deſcrib'd at large by *Fabritti*, a celebrated Architect amongſt the *Romans*, with Verſes ſuitable to ſo great a Work;

and

and the Places through which they came are now in Part to be ſeen, both at *Rome* it ſelf, and in the Prints that give an Account of it; all which is very judiciouſly collected together in *Montfaucon*'s elegant and noble Deſcription of the Antiquities of that great and glorious Metropolis.

" The Leaden Pipes were at leaſt nine Foot long, and they made " them of bended Sheets or Plates of Lead, of different Thickneſſes, " according to the Proportion of the Largeneſs of the Pipes; theſe " Pipes had likewiſe their neceſſary Declination or Sloping, and if " any Valley was in the Way, (by an unneceſſary Expence without " Doubt,) they made it equal to the Level with a Wall; they like- " wiſe had many Vents, to give the Water Air, and to know where " to mend the Pipes." And theſe, by the Deſcription given of them, are much ſtronger than the Mould Pipes now made; but of that in its proper Place; the Purport of this Chapter being purely deſign'd to ſet down all that is neceſſary as to the conveying Water by large Aqueducts, whether open and covered, or by ſmaller Drains, as the next is for all Sorts of Piping, whether in Earth, Wood, Lead, or Iron.

The Ancients (as is before intimated) choſe rather to bring their Water in large Aqueducts, that were ſo high that a Man might go upright in them, in order, as it may be ſuppos'd, to mend the Pipes; and had three or four Kinds of Water brought from different Springs, for different Uſes, in different Pipes; ſo that the whole Structure of their Conveniences for Water, was of an immenſe Height, and brought at an immenſe Expence, which had certainly the good Effect of keeping the Water clean and pure as it came out of the Spring; whereas Water that is brought in open Carriages, as the *New River* and other Waters are, is ſubject to be ſully'd by Land Floods, and to receive a Kind of a muddy Earthy Taſte and Tincture from the ſeveral Soils through which it paſſes, in thoſe ſo great Diſtances which it is generally brought.

But as theſe are immenſe Expences, and ſuch as are ſcarce conſiſtent with the Pockets of any but the greateſt and moſt opulent Princes and States; and as ſuch enclos'd Aqueducts with Pipes, ſome of them but of a moderate Size, are not likely to ſupply Gardens, and large Cities and Towns with the Quantities of Water which are generally there wanted, theſe open Carriages are abſolutely neceſſary, eſpecially where the Property of the Ground through which you bring them is eaſily to be come at, that I can't but recommend them beyond all encloſed Aqueducts, both as to Cheapneſs, and alſo as to the Quantity of Water they produce: To all which may be added,

 that

that although the Water may be more ſully'd, yet by the kind Affluence of the Sun and open Air, it muſt be ſweeter, and ſtripp'd of thoſe corroding Qualities that make it ſo injurious to Man, Beaſt, Plants, &c. all which thrive better from Water that is taken out of Ponds or Rivers that run gently, than out of cold Springs.

This being premis'd, the next Thing to be conſider'd is, the *Profile* or Dimenſions of ſuch an open Current or Courſe of Water; after which we ſhall conſider the encloſed ones of more ancient Make, which do indeed bring Water to any Place clearer and leſs turbid, and therefore the fitter for Drinking, and the Butler's Uſe.

The Depth and Breadth, or, in other Words, the *Profile* of ſuch Carriages, may be according to the Quantity of Water you want, or according to the Supply you have; though I think it cannot well be leſs than four or five Yards wide at Top, and four Foot deep, that there may be Room for that Sediment with which Water is naturally endued, by its running through Soils of different Kinds; beſides, ſuch a Depth, requiring Banks that are ſloping, to which you can't allow leſs than one Foot and a half, or two Foot horizontal for one Foot perpendicular, leſs Width than that won't do; but if it is deſign'd to be a navigable Channel for larger Boats, then you can't allow leſs than thirty or forty, as the Canals that go between Town and Town in *Holland* generally are.

You have been already told how to take the Level from one Place to another, as alſo how all Levels are to be adjuſted, with Allowance for Friction, the Interpoſition of Air, &c. and what Fall is proper to be allow'd for the Paſſage of Water from one Place to another; it now remains that ſome Directions be given how this open Carriage or Drain, call it which you will, be made; in doing which I have a conſiderable deal of Experience.

You muſt be ſure, in the firſt Place, to keep up as much as you can in whole Ground; and by the Side of ſuch Hill or Valley as lies near you, for that no Banking can be ſuppos'd to be of equal Solidity and Security with ſettled Ground; and you muſt be ſure alſo to clear away all Sorts Trees, for old Tree Roots will rot and let the Water out, and the Roots of young Trees will be equally dangerous, in as much as they will by the blowing of the Wind looſen the Banks to that Degree as that the Water will run out much to waſte there: To this may be added, that rocky Ground, Fox and Rabbet Earths, are Soils very dangerous to make ſuch Works, as I can aſſure my Reader from dear-bought Experience.

If good Clay can be procur'd near at hand, it is requiſite it ſhould, eſpecially where there is a Neceſſity of raiſing Banks entirely new, or for the ſtopping of Rocks, Fox, or Rabbet Earths, &c. but in other

 Ground

Ground where you come through that which is whole, there will not be Occaſion of that great Care, eſpecially if your Supply be any thing conſiderable; but one of the chief Cares, will be to cloſe your Joints well between your new and old Ground, and when you build new Banks on old Ground, be ſure to go down with your new Clay or Ballaſt two or three Foot lower than that Ground, and two or three Foot wide, and always mind to mix your old and new Ground together by a Toothing, in ſuch a Manner as the Bricklayers do, that leave it for one Brick to join another.

Sure it is, that whether it be a Ballaſt, or ſtrong or indifferent Clay, ramming is very neceſſary, or by laying the Strata's but a Foot thick, or thereabouts, at a time, the Labourers may tread or wheel over it, keeping as exact a Slope towards the Trench as if it was a Garden one; and in all hollow Places it may not be improper to fill them up with waſte Earth, not ſo much to ſave or hold Water, as to give the proper Baſe and Support to the Foot of the Bank.

The inward Sides of the Slope of the Bank, ſhould alſo be well beat with a large Hedge-Stake before you pare them with a Spade, which it is requir'd you ſhould do. I ſhould not adviſe to allow leſs than ſix or eight Inches, or a Foot in a Mile (if you can have it) Dependance; but ſurely leſs than four or five Inches is abſolutely neceſſary, notwithſtanding what Sir *Jonas Moore* and ſome others have noted on this Head. As for the *Profile*, it will be ſeen *Fig.* 1. *Tab. ſeq.*

The next Method of conducting Water, is that uſed by the Ancients in their enclos'd Aqueducts: But this is ſo very expenſive that I ſhall not repeat it here, but rather refer my Reader (if his Curioſity ſo leads him) to the Works of the celebrated *Fabretti*, which are to be had in ſome of our Bookſellers Shops; and from him Monſieur *Montfaucon*, who has given the Draft of the famous Aqueduct of *Metz*, and other Places; nor are the Works of *Vitruvius*, *Palladio*, and other Architects of *Rome*, to be paſſed by on this Occaſion.

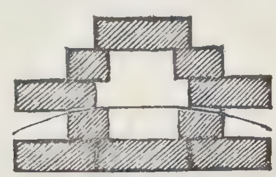
But to proceed to thoſe Works, which are made Uſe of by the Moderns:

The firſt is, that of Aqueducts made of Brick or Stone; in neither of which we run to that Expence the Ancients did, not making them ſo large, nor any Way ſo expenſive. A Drain of a Foot ſquare in the Inſide, made with either of the two Materials, Stone or Brick, (but Brick is the deareſt,) the other not coſting above Ten Pence Twelve Pence a Yard, though at that Size they will convey vaſt

Quantities of Water: But the greateſt Inconvenience that attends them is, that if you are to convey the Water a-croſs a Valley, from one Hill to another, theſe Stone or Brick Drains will not do it, and can be only uſed where the Water is to run ſtrait, or is to run round upon the Precipice or Side of a Hill upon one Level. You may, indeed, make Wooden Troughs a-croſs Valleys, as above, and ſupport them with a Frame of Wood; but there are many Inconveniences attends them, as the Drought in Summer, which will chop and tear them to Pieces, ſo that the Water will be in Danger of being loſt, or the Trough ſubject to be cut or broke to Pieces by ill-deſigning Perſons; in all which Caſes under-ground Conveyances in Wooden, Leaden, or Earthen Pipes, are the beſt.

But wherever you can carry your Drain ſtrait, (or even round,) and it be an eaſy gradual Declination, there Brick or Stone Aqueducts or Drains are the cheapeſt and beſt, eſpecially where your Spring is large, as ſix or eight Inches Bore; and then you muſt lay it in very good Mortar, laid in the Spring, and ſuffer'd to dry before you turn the Spring into it, bedded alſo in Clay; and when cover'd over at Top, as it ought to be, with flat Stone, Clay muſt be ramm'd on the Sides and Top of the ſame, to prevent any Effluxions of the Water.

But the Brick Drain is the next in Courſe: Theſe can't well be made above ſix or ſeven Inches ſquare in the Inſide, becauſe a good large Brick, with which the Bottom and Top is made, is not above nine Inches long, and it muſt lap over an Inch on each Side at Top, and at the Bottom there muſt be a ſtretching Brick on each Side, to ſupport the Side-Wall and Back, or rather End. The Conſtruction of this Drain you will ſee in the Figure following; where the Bricks are placed, Header and Stretcher, in the Manner they are when made into a Drain; the middle Brick mark'd a, may be any bro-



ken Bricks: Every Yard will take up about three Quarters of a Hundred of Bricks, which, at eighteen Pence a Hundred, comes to between thirteen and fourteen Pence, and the Lime and Setting may be worth about two Pence, and the digging and claying a Groat or five Pence more, in all about twenty Pence; and, perhaps, in Countries where Materials

Materials and Workmanſhip is cheaper, it may be done for ſixteen or eighteen Pence a Yard.

But there is another cheaper Way of Brick-Drain yet; and that is when you make a Hollow or Semi-circle of two or three Inches in Bricks, (about four or five Inches thick, and the uſual Length:) Theſe Bricks, when plac'd together, and when ſet in Terras or very ſtrong Mortar, well dry'd before you uſe it, is the cheapeſt and moſt durable Method of any for conveying Water; about eight Bricks will do a Yard, which Bricks are worth three Shillings a Hundred, the eighth Part whereof is about four Pence Half-penny, and the Digging, Laying, and Mortar, may be worth about three Pence or four Pence more. And this is the cheapeſt Method of all; but muſt be laid in Clay, as all other Drains and Piping ſhould.

I Might have enlarged a great deal more, in this Chapter, on the Methods which the Ancients made uſe of in their Conveyances of Water, but that they are very plainly deſcrib'd by the Editors and Commentators on *Vitruvius*, and the other Architects of *Rome*, *Italy*, and *France*; to which I refer my Reader.

CHAP. IX.

Of the ſeveral Kinds of Pipes for the Conveyance of Water, whether Lead, Iron, Earth, or Wood.

It has been already noted, from *Vitruvius*, *Lib.* 8. *Cap.* 6. "That "the Ancients had but two Sorts of Pipes, through which they "conveyed their Water; the firſt was made of Lead, which was of "Sheets nine Foot long, and turn'd in at Top;" not unlike, as appears by the Deſcription, ſome which were made ſome few Years ago for the Rt. Hon. *George Dodington*, Eſq; one of the Lords of His Majeſty's Treaſury, at his fine Seat of *Gunville* in *Dorſetſhire*, the Work of a very ingenious modeſt Man, and a good Plumber, Mr. *Watts*, of *Brackley* in *Northamptonſhire*.

These Pipes are join'd together without Solder, by what the Workmen call Flanckets, which are Rings made of Iron, that may be ſcrew'd as tight as you pleaſe at the Joint, the Noſe of one Pipe going into the Tail of the other; and in order to keep the Water from getting out at the Joint, there are (as I remember) proper Bandages of Leather, that cloſe it up by the Compreſſion of the Flanckets, under which may alſo be put Taw made of Flax or Hemp, dipp'd either in Oil, Pitch, or Tallow, which will make a cloſe Cement

to keep the Water in, and over which the ſaid Flanckets are ſcrew'd. Theſe Kind of Pipes are much to be preferr'd before thoſe made in Moulds, in as much as they are caſt without thoſe Flaws and Holes that often happen in Mould-Pipes, and as they are turn'd in at Top, and burnt, (as the Workmen expreſs it,) they are much ſtronger. Nor is there that Expence in Solder (beſides many other Advantages which I ſhall enumerate in their proper Place) which is in other Pipes. It is true, they are dearer than any other Pipes are, and are chiefly fit for large Pockets; but then they laſt much longer.

But the cheapeſt Kind of Pipe, which is now uſed, is that which is made of Earth, and for which Mr. *Edwards*, a Gentleman of *Monmouth*, has a Patent; this Kind of Pipe, *Vitruvius*, *Lib.* 8. *Cap.* 6. *prædic.* tells us, were made by the *Romans* of Potter's Clay two Inches thick, and were join'd together with Mortar mix'd with Oil, and when they had a Joint to make, they made uſe of a red Free-ſtone which they pierced through to receive the two Ends of the Pipes, and to ſtrengthen and ſecure them in the Nature of a Bandage.

Some of theſe Pipes have been, as I am inform'd, found about *London*, the Laying whereof, by ſeveral Circumſtances, being ſuppoſed to be owing to that great People when they were Inhabitants of this Iſland; but the Joints were ſecured by a piece of Sheet-Lead, which was wrapt round the Joint, ſome whereof I have been told have been taken up in *Hyde-Park*, belonging to the ancient Water-works there.

Those which are now made, and for which Mr. *Edwards*, before mentioned, has a Patent, are not above half an Inch thick and three or four Foot long, but they are ſo exactly made and fitted in the Joint that no Water can poſſibly come out of them. They are ſold from twelve Pence or two Shillings to half a Crown a Yard, and ſometimes cheaper, according as they are more or leſs in Diameter, and are exceeding uſeful in all Places where they lie free from Coaches or Carts going over them. They are alſo ſo ſtrong, that, according to a Letter I have lately ſeen from the Patentee, he has laid a Reſervoir or Head of 300 Foot high of Water; and this, I take it, is at the Right Hon. Mr. Baron *Price*'s, in *Herefordſhire*. But that is nothing to what follows by-and-by. But to proceed:

Besides what the ſaid Patentee makes in the Country, a very ingenious Potter, and Neighbour of mine at *Vaux-hall*, Mr. *Aaron Mutchell* by Name, makes thoſe which are excellently good, not only for the ſaid Patentee, but alſo for any other Gentleman who may have Occaſion for them, he having been one of the firſt Inventors of them, (as he is alſo

of

of ſome of the handſomeſt Vaſes, Flower-Pots, and Urns, which have been as yet any where made, as ſtrong, and equal in Goodneſs to the Patentee himſelf, though now he acts by Agreement under him.

THIS I thought proper to ſay, that Gentlemen may know where to find ſo extraordinary a Man in this Buſineſs.

To conclude: Before I paſs over theſe Sort of Pipes, I can't but inſert a Tryal which was made of them the 24th, 25th, and 26th of *July* laſt, at the *York Buildings*, before the Rev. Dr. *Deſaguliers*, when they were fairly try'd with all the Compreſſion of Air and Water that that Engine could lay upon them, and without making the leaſt Fracture, either in the Pipes, or the Cement which join'd the Pipes together; and this Tryal was even before the Plumber of theſe Works themſelves, a general Account of which is to be found in the the *Evening Poſt* of *Auguſt* 1, laſt. All which I mention, becauſe though they are certainly uſeful in the conducting of any depending Water, yet I could not (from any Thing I had ever obſerved of this Kind) promiſe they would be ſtrong enough to bear the forcing of the Engine.

THESE Kind of Pipes are made of a Clay equal to that of which the Tiles of the ancient *Romans* were made, are alſo uſed in the Inſides of the Walls of Houſes, and are affix'd likewiſe to the Outſides of the ſame, in the Manner as Lead is, even from the lower to the uppermoſt Floor; and receive and diſcharge the Water from the Roof and Gutters of ſuch Houſes, as effectually as any Pipes made of Lead or Wood, and are ſold for a ſixth Part of the Value of Lead, and more than one half of what Wood coſts.

THIS new Invention, or, at leaſt, this great Improvement of an ancient one, is of ſo great a Uſe to the Publick, that I thought I could not do better than enlarging on it.

But to proceed: There are many other Sorts of Pipes which have been uſed by the Moderns, which were, as appears by what *Vitruvius* has wrote upon this Subject, entirely unknown to the Ancients, ſuch are thoſe of Wood, as Alder, Elm, Oak, Beech, and Iron, (the laſt of which are uſed in *France* more than any where,) but till of late have found little Footing in *England*.

PIPES made of Alder are the cheapeſt of all, though not the ſtrongeſt, the Wood, Boring and all, being not worth above Ten Pence or Twelve Pence a Yard; but the Diameter of ſuch Pipe, is generally but ſmall, an Inch and a half, or two Inches, being the utmoſt Bore it is capable of having, nor is it ſtrong enough to

bear much Force, but only to conduct a little Spring any ſmall Length, and upon a gentle Current.

In and about *London*, the Pump and Pipe-Makers uſe Firr for Pipes, where the Stream is not great, which, as it bores eaſy, ſo it is cheaper than that of Elm; but then it is not ſo ſtrong nor ſo durable as Elm Pipe is, and is fit only for Works where neither the Riſe nor Declivity are either of them great.

Elm Pipe is the next I ſhall mention, as being much ſtronger than any of the former, and of known Uſe for the conveying of Water, and for that it will lie longer under Ground, and in the Wet and Water than any other Sort of Wood Pipe (Oak excepted) will. Now as theſe are generally made of ſmall Trees and Saplings of different Dameters, the Prices will be different, becauſe thereby they will be either ſtronger or weaker, and conſequently bear a greater or leſſer Force, proceeding either from the Force or Lifting of a Wheel, or the Cylinderical Weight of Water which lies upon them where Reſervoirs lie high; and it is for Want of Care and due Obſervation in this Kind of Piping, that Water-Works often miſcarry where the Bores are larger than they ought to be, and the Outſide or Shell too thin, eſpecially in veiny crooked Trees.

Elm fit for Pipes may be cut down, hewed, or bored, from eight Pence, ten Pence, twelve Pence, to ſixteen, eighteen, or twenty Pence a Yard running, Timber and all, five Pence or ſix Pence a Yard Boring being a ſufficient Allowance. But for the quicker Expedition of this Work, I have given the Draught of an Engine for boring by Water, which will be exhibited in its proper Place.

I have examined the Prices of Elm Pipes about *London*, and find, as hinted before, that they are according to the Thickneſs or Strength of the Pipe, which ought to be either more or leſs, according to the Weight they are to ſuſtain.

The following Prices are taken on a Medium, being Sizes of Pipes which are generally uſed.

		s.	*d.*	
7 Inch Pipe	is worth about	5	0	*per Yard.*
6 Inch Pipe		4	6	
5 Inch Pipe		3	0	
4 Inch Pipe		2	6	
3 Inch Pipe		2	0	
2 Inch Pipe		1	3	

These may be all had at Mr. *Hewit*'s, and other Pump-Makers, in *Lambeth*, and other Places on the *Bank-Side*.

Those

Those who have the moſt to ſay againſt Elm Pipe, urge, that there is a great Waſte of Water at every Stroke of the Engine, which forces theWater with great Violence through the Pores of the Tree: But this I take to be an Eaſe to the Work, and not at all different from Nature, but is rather a Relief than a Burthen to the Machine and the Paſſage of the Water in the Pipes, which is very often in cloſer Bodies ſo Wind-bound, that it won't paſs. There is another Convenience which attends theſe and all other Wooden Pipes; and that is, that you may at any Time, when Pipes are Wind-bound, which they often are, when they lie long unus'd in the Ground, that then you may bore a Hole at the very Place where you perceive the Stoppage to be; which is what you can't ſo well do in thoſe other Pipes which are made of Metal.

Another Sort of Elm Pipe, which is, I conceive, as ſtrong, if not ſtronger, and more durable than the former, is made ſquare, and of Elm Plank, the Contrivance of a late worthy ingenious Gentleman and Friend of mine, *John-Thyrle Ernby*, Eſq; of *Whetham*, near *Sandy-Lane*, *Wilts*, on the Road to the *Bath*.

The Boards of which thoſe Pipes are made are generally about ten Inches ſquare, and an Inch and three Quarters thick, but you may have them of a Foot or fourteen Inches ſquare, but then they muſt be two Inches, or two Inches and a Quarter, or two Inches and a half thick.

The Sides are to be well groov'd into the Bottom and Top, and the Joints are to be well pitch'd, or ſtuff'd with Tow or Hemp dipp'd into Pitch and Tar, to keep the Water from oozing out; after which they are to be banded or collar'd at about five or ſix Foot aſunder, with Collars or Bands made of Elm Slabbs, or Planks, cut out of the Sides of the Elm, and this will be ſtronger, more natural, and more durable than any other Bandages are, and will ſave Iron Hoops, which are expenſive.

A Board or Boards of ten Inches ſquare, will, when groov'd in at Bottom and Top, make a ſquare Pipe about four Inches and a half, or five Inches ſquare, which laſt is near equal to a circular Pipe, whoſe Diameter is ſix Inches.

To proceed in the Work, be provided with Taw, or coarſe Hemp, as alſo Pitch and Tar, and dipping the Taw or Hemp into the Tar, put it into the Groove or Joint, and then let the Workmen knock the Boards together in the Groove, with all the Might and Strength they have, it being in the Cloſeneſs of this Joint that the Security of the Water in the Pipes conſiſts.

This done, put on the Collar or Bandage, one at each Joint, the Boards being about nine or ten Foot long, and another Collar in the Middle, putting the fmall End of one (fo made, as you do in Elm Pipe which is bored) into the great End of the other.

Hence follows an Eftimate of the Expence of this Kind of Pipe, or rather Trough, which I recommend more than that which is bored; for that in the firft Place it is ftronger, and may be made five, fix, or feven Inches fquare, which will carry more Water than bored Elm Pipe of the fame Diameter will.

In the next Place, there is lefs Depopulation and Wafte in cutting, (a few large Elms at full Growth, being fufficient for this Purpofe;) whereas when you cut them down fmall there is a great Wafte made. And, in the laft Place, it being all Heart, it will not be fo fubject to break or burft as Elm bored will.

Here follows the Expence of 330 *Yards running, which I my felf caufed to be made in the fame County of* Wilts.

	s.	*d.*	*q.*
For 20 Tun of Timber at 30 Shillings per Tun,	30	0	0
Felling and Hewing of ditto, at 8 Shillings per Tun,	8	0	0
For 330 Yards of Workmanfhip, at 4 Pence per Yard,	5	11	0
For Nails, Tar, Taw, or Hemp, Banding, Collaring, and Laying included, at 3 Penee per Yard,	4	2	6
	47	13	6

By which it appears, that the whole 330 Yards comes to forty feven Pound thirteen Shillings and fix Pence; which being reduc'd into Shillings, Pence, and Farthings, and divided by the faid 330 Yards, it comes to about two Shillings and ten Pence a Yard; whereas Lead Pipe of fuch a Dimenfion would coft at leaft twenty Shillings a Yard, and bored Elm five or fix Shillings. But I have fince found that four Pence a Yard is too little for the Workmanfhip by two Pence, and fo it will coft juft three Shillings a Yard, which I take to be a very reafonable Price.

One of the laft Kinds of Piping which is generally made of Wood, is Beech, which being of a more firm and folid Contexture, and lefs porous than Elm or Oak, will lie under Ground longer than either of them, as may be feen in all Mill-Work, in which this Wood is much ufed; but like many other Woods has an Inconvenience attending it, that it bores pretty hard, is brittle, and not fo tough grain'd

as

as Elm or Oak is; beſides, the Boughs don't run ſo ſtrait, generally ſpeaking, as Elm does, and therefore the Shell of it ought to be very thick, not leſs than five or ſix Inches to keep it from burſting; and in ſuch a Caſe the Bulk or Dimenſions of it ought to be twelve or fourteen Inches diameter, one with another, when you may venture at a Pipe of two or three Inches Bore; and though its ſomething difficult to bore, yet the Water will be leſs ſubject to ooze out, than at any of the others, Oak itſelf not excepted.

THIS Sort of Piping, the Property of the Wood, digging the Trench, Boring, Laying, Claying, and Banding, will be worth three Shillings, or three Shillings and ſix Pence *per* Yard, for a Bore of four Inches, and ſo on proportionably leſs, as the Wood or the Bore is leſs: But then it muſt be obſerved, that it is the neareſt the Goodneſs of Lead of any that is a four Inch Pipe, which Lead will coſt fifteen or ſixteen Shillings; as will by-and-by be ſet more plainly appear.

THE very laſt Kind of Wooden Pipe is Oak, which indeed is very ſtrong, and laſts a great while, there being ſome Trees of that Kind which (under my Superviſal) were dug out of the Foundations of *Blenheim*-Bridge, that were, though as black as Ebony, yet as ſound as Brazil it ſelf, and might in all Probability have no other Date than that of the Deluge it ſelf. But as the Limbs are generally crooked, and that all the young Bodies together, with the whole Timber it ſelf, is too good for thoſe Purpoſes, I ſhall omit ſaying any Thing more on this Head.

THE next Piping to be mentioned, are thoſe made of Potters Earth, of which I have ſaid ſomething already. There are two Kinds of theſe at leaſt: They are of two Thickneſſes in the Shell; the firſt being the moſt in Uſe in the Country, is not above the Thickneſs of two Crown-Pieces at moſt; but this is ſo thin, that it is fit only to convey Water a little Way were the Fall is not great. Theſe may be bought in many Places of the *Weſt* for ſix Pence a Yard.

THE other is the new-invented ones already nam'd, which nevertheleſs are not above half an Inch thick in the Shell, more being, according to the Opinion of the Potters which make them, entirely uſeleſs, at leaſt they can't burn them ſo well.

THESE are excellent Pipes when glaz'd in the Inſide, as they ought to be, to keep Water ſweet; and how they will do in Force-Work has been already ſet down.

THERE is a Complaint made againſt them, how true I know not, That there is a Weed apt to grow at the Place where they are jointed together, the Fibres of which are apt to choak the Pipe up:

But this, if true, may certainly be prevented, if you put on a thin Bandage of Lead round the Joint, or if you put a Collar of Stone or Wood, to ſtrengthen them, you may prevent that Miſchief.

The Manner of mending them when broke, has been another Objection which has been brought againſt them; for if the Joint be made of ſuch a Cement as that the Pipe will rather break any where than there, it does not ſeem eaſy to tell how they are to be amended. Now in anſwer to this, the Joints that I have ſeen at my ingenious Neighbour's at *Vaux-hall*, ſhoot ſo cloſe together, that there is little Occaſion of any Cement; but when they do, Taw dipp'd in Pitch and Tar, or any other Cement of that Kind, will effectually ſtop it, at leaſt, the Loſs of Water will not be great where the Supply is any thing large, and then they may be uncollar'd and mended at Pleaſure. But of this more in the Notes on this Book.

There is one Thing to be obſerv'd, which is certainly true, and that is, that they won't do in High-ways and Streets, where Carriages and Coaches are to croſs them, but on all other Accounts they are excellent Pipes, and a cheap Conveyance.

Of all the Sorts of Piping for the Conveyance of Water, that of Lead is preferrable, (eſpecially thoſe which are made of Sheet-Lead, and burnt at Top,) were it not for the Expence, whether we conſider them as being more pliable to lay up and down Hill, as they are eaſier and more firmly jointed to one another, or as they are as durable as any other, and if well caſt of a much cloſer Contexture.

In Pipes of Conduct, and where Water is conveyed a great Way, the Diameter ought to be ſix or ſeven Inches, but four or five Inches at leaſt, becauſe in Pipes of that Size there is leſs Friction and Windboundedneſs than in theſe which are ſmaller, and conſequently the the Water will flow the better and riſe up to the Height of its firſt Head more regularly, and in greater Quantities.

It muſt indeed be own'd, that a Pipe of Conduct of ſo large a Dimenſion as I have juſt now been naming, is ſuch an Expence, that few Noblemen or Gentlemen are willing to be at the Expence of, eſpecially in very great Lengths, where the Expence is almoſt immenſe; Pipes of that Kind, without a Shell of Thickneſs proportionable to it, being worth from twenty five to forty Shillings a Yard, according to the Height of the Reſervoir, or the Force they are obliged to ſuſtain.

A Pipe of Conduct therefore of the cheapeſt Kind, muſt be at leaſt four Inches and a half or five Inches Diameter, and this will coſt at leaſt ſixteen or eighteen Shillings per Yard. This has been the Occaſion that in many Places they have reduc'd their Pipes

of Conduct to three Inches Diameter, which is indeed too little, though thereby the Expence is reduc'd to about ten or twelve Shillings per Yard, according as the Price of Lead is.

It will be to little Purpoſe, for me to urge that Pipes are dearer or cheaper in Proportion to their Dimenſions and Thickneſſes, and conſequently to the Price of Lead, and the Allowance in Weight which is made to every Foot or Yard; but the following is a Calculation made for a Perſon of Quality, for whom I have had the Honour to be employ'd; and where Lead, Caſting and all, is reckoned at twenty two Shillings per Hundred.

To a Pipe of three Inches Bore, there is allowed forty five Pounds a Yard; and this is worth about nine or ten Shillings a Yard, when Lead is worth from twenty two to twenty five Shillings per Hundred Weight, allowing for Waſte.

To a Pipe of two Inches three Quarters forty Pounds is allowed, which is worth between eight and nine Shillings a Yard.

To a Pipe of two Inches and a half, thirty ſix Pounds is allowed, and then it is worth about ſeven or eight Shillings a Yard; but it would not be amiſs to add five Pounds more to every Yard, though it aggravate the Expence ſomething.

To a Pipe of two Inches Diameter thirty Pound of Lead is allowed, which is worth about ſix Shillings per Yard.

But of all the Pipes made of Lead, of what Size ſoever, thoſe which are join'd together by Flanchets (as has been already intimated in the Beginning of this Chapter) are the beſt, which may eaſily be taken up, and ſcour'd or cleans'd, whenever the Owner pleaſes: Becauſe, as *Marriotte* truly obſerves, there is, even in the fineſt Water, a Sediment, which will in time petrify, incruſtate, and grow hard, and will ſtop up the Pipe, which can never be clean'd again where Pipes are ſolder'd together at the Joints with Solder, as Pipes generally are. And this is one (amongſt ſome other of the Misfortunes,) which attend all Water-Works, and is the Occaſion of their being ſpoiled.

I Have already mentioned ſomething concerning the Lead which is proper to be allowed to Pipes in general, according to the Proportion or Diameter of their Holes: But when Reſervatories are very high, or Water is rais'd by an Engine to great Heights, or carried to great Diſtances, there Pipes of Conduct are in Danger of being often broke, if the Shell is not thick enough, eſpecially up and down Hills, and through deep Valleys; and it would give a Man a good Deal of Uneaſineſs, after he had been at great Expence, if his Pipes ſhould happen to burſt through the Defect of the Solder,

or the Weakneſs of the Pipes. At the ſame time Care ſhould be alſo taken, on the other hand, not to make them thicker than is abſolutely neceſſary, ſince a ſmall Addition in long Lengths would greatly enhance the Price.

But it is proper we ſhould underſtand from Experience, (as well as from what *Marriotte*, and others, have delivered on this Head,) that the Thickneſs of the Metal, or Shell of the Pipes, be increas'd or diminiſh'd in Proportion to their Diameters, the Heights of the Reſervoirs from which the Water falls, or the Height to which it is to be rais'd by Engines, and laſt of all, the Lengths or Diſtance which Water is to be carried; all which adds to its Cylinderical Weight, and conſequently the greater Thickneſs of Metal in the Pipes.

For Example, according to *Marriotte*, when a Reſervoir is ſixty Foot high, and the Pipe three Inches Diameter, the Metal muſt be half a Line in Thickneſs, which is the twenty fourth Part of an Inch; but as this ingenious Author undoubtedly means Copper, which is harder, ſtronger, and of a cloſer Contexture than Lead, I ſhould not adviſe leſs in ſuch a Caſe than three or four whole Lines, which is one third or one fourth Part of an Inch; and to a Reſervoir 100 or 120 Foot high a whole Inch, becauſe of its great Height.

If the Pipes are both wider and higher, then the two Proportions muſt be alſo obſerved: Thus if a Pipe comes from a Height of ſixty Foot, and the Diameter be ſix or eight Inches, you muſt take the half Line in Copper, or rather three Lines, or the Quarter of an Inch in Lead, becauſe of its Height of ſixty Foot; and for the Thickneſs, you muſt work by the *Rule of Three*, ſaying, *If nine, the Square of three Inches, requires three Lines thick of Metal, what will thirty ſix, the Square of ſix Inches, require?*

EXAMPLE.

As 9 is to 3, ſo is 36 to a 4th Number requir'd.

```
          3
         ---
     9) 108 (12 Lines is the Anſw.
         18
         ---
```

So that a Pipe of ſix Inches Diameter, when it comes from a Reſervoir ſixty Foot high, ſhould be twelve Lines, or one Inch thick; near or according to which the following Table is calculated.

But

But before we come to it, there is another Thing to be determined, and that is the Diameter of the Adjutages; a Piece of Knowledge that undoubtedly belongs to this Head.

The ingenious Author of the *Theory and Practice of Gardening*, ſays, that it may be taken for a certain Rule, that the Bore of the Adjutage ought to be four Times leſs than the Diameter or Bore of the Pipe of Conduct, that is, they ſhould be in a Quadruple Proportion thereto, ſo that the Column of Water may be proportionable, and the Quickneſs of the Motion in the Pipes may be equal: Beſides, as is elſewhere obſerved, there is too great a Friction and Wear in ſmall Pipes, when the Quill is too big, and in the Bore of ſmall Quills when Pipes are too large: All this, I ſay, likewiſe depends on Calculations of this Kind, which will neceſſarily be included in a Table, where the Diameter of Pipes of Conduct, Thickneſs of Metal, &c. are contain'd.

Agreeable to what I have before obſerved, the Calculations *Marriotte* has made on this Head, are undoubtedly for Copper, Lead being not ſo much us'd in *France* as it is with us in *England*, eſpecially in Time of War, when they have none but what they get from our good Friends and Allies the *Dutch*. On this Account I thought it was proper for me to pitch upon a Pattern of a Lead one, which ſhould determine all that is requir'd on this Subject; which I have done from a Pattern in the *Weſt*, (the Work of a very good Plumber at *Hungerford*,) which by all good Judges is accounted a moſt excellent one.

The Pipe is four Inches Diameter, which is generally ſuppoſed to be a good Pipe of Conduct, (though in ſome Caſes more is requir'd,) and about equal to the Expence that moſt Noblemen and Gentlemen are willing to be at.

The Thickneſs of the Metal, which is of Lead, is ſix Lines, or half an Inch: To regulate then the Thickneſs of other Metal to it, ſay, as before, *If ſixteen, the Square of four Inches, requires ſix Lines; how much does thirty ſix, the Square of ſix, require?*

EXAMPLE.

16 : 6 : 36
6
———
16) 216 ($13\frac{1}{2}$ is the Anſwer.
56
———
8
———

By

By rejecting the Fraction it appears, that the Thickneſs of the Metal requires to be thirteen Lines, or one Inch one twelfth: And from this it is that I have form'd the Column concerning the Thickneſs of Metal in Pipes, which is (I take it, without any conſiderable Variation) agreeable to Truth, which expreſſes alſo the Height that the Water coming from the Reſervoir will riſe. Here follows the Table.

Height of the Reſervoir.		Diameter of the Pipes.		Thickneſs of the Metal.		Diameters of the Adjutages.		Height the Water will riſe to.	
Feet.	Inch.	Inch.	Lines.	Lines.		Lines.	Parts.	Feet:	Inch.
100	0	7	00	15½	16	12 or	15	80	00
86	4	6	00	14	00	12	14	70	00
72	0	5½	00	12	13	10	12	60	00
58	4	5	00	9	9	8	10	50	00
45	4	4¼	00	7½	8	7	08	40	00
33	0	3	00	6½	7	7	00	30	00
21	4	2½	00	5½	6	6½	00	20	00
15	9	2¼	00	4	5	6	00	15	00
10	4	0	25	3½	4	5	00	10	00
5	1	0	22	3	3½	4	00	5	00

Thus far of the Diameters of Pipes of Conduct, Thickneſs of the Metal, Diameters of the Adjutages, *&c.* as are, or ought to be proportionate one to another. But if any Gentleman has a Mind to have his Pipes of Conduct larger than any above mentioned, he may; the Uſe of this Table being chiefly calculated for all proportionate Heights.

What I have to add to this Chapter, is, to give ſome Account of Iron Pipes, which are now growing into great Uſe, and are, in reſpect to their Cheapneſs, the beſt Pipes, Clay excepted, which are now made, eſpecially if the Metal is well proportioned and melted. But it muſt be obſerved, that the Caſting of them very ſmall is no great Advantage, the beſt Sizes being from ſeven or eight to five, four, or three Inches Diameter; the firſt of which will coſt about twenty Shillings a Yard, which is a great deal cheaper than Lead; and the laſt, from ten or twelve to fifteen or ſixteen Shillings, or perhaps cheaper, as they are more or leſs in Bulk and Diameter.

These Kind of Pipes are the moſt durable of any yet mention'd: They are caſt about two Yards, and ſometimes three Yards long, and that but ſeldom: They are join'd together by Flanchets, as may be ſeen

ſeen in the Water-works on *London-Bridge*, or as I have before deſcrib'd thoſe which are made at Mr. *Dodington*'s of Lead, as I have been well inform'd, by a very ingenious Gentleman, if well made, will laſt, as it were, for ever.

This, and all Foundery-Works of this Kind, are well perform'd, and Gentlemen may expect to be dealt well with, by Mr. *Bowen*, at his Foundery near *Marigold-Stairs*, *Southwark*, where Garden-Rowlers, Palliſadoes, and other caſt Iron-Works, are to be had. And ſo much as to Pipes.

CHAP. X.

Of Reſervoirs, Baſins, &c. the Method of making them, their Conſtruction, proper Extent, Depths, and other Dimenſions.

We are told by *Vitruvius*, *Lib.* 8. *Cap.* 6. "That the Me-"thod the Ancients us'd in making their Walls and Ciſterns "to receive Rain and other Water, was under Ground, and of a ve-"ry large Extent; and Walls were built on the Sides and at the "Bottom with Mortar made of ſtrong Lime, Sand, and Pebbles, "well beaten together;" Claying not being, it may be ſuppoſed, ſo well known, or to be had in ſuch Quantities as now it is.

"Of theſe, ſays our oft-quoted ancient Author, they made ſeve-"ral, one after another, through which the Water was to paſs, to "the End, that the Sediment might remain, (if any there was) in the "firſt and ſecond, and ſo that when the Water was arrived at the "laſt it might be clear. They likewiſe put Salt into their Ciſtern-"Water to make it more ſubtle.

In this Manner alſo were the remarkable Ciſterns of *Roſelayn* made, *viz.* with no other Materials, as has already been intimated, than Gravel and ſmall Pebbles conſolidated together by a ſtrong tenacious Cement, perhaps, ſuch as Terraſs-Mortar, or the like.

And certain it is, that too great Care can't be taken in making thoſe uſeful Reſervatories, as daily Experience ſhews, eſpecially if it be upon a dry Gravel or Sandy-Bank, and is to lie above Ground, as is evident from that very handſome one behind his Grace the Duke of *Chandois*'s intended Building near *Cavendiſh-Square*; where the

 Expence

Expence of making and fitting it (with how great Succeſs, I can't tell) has doubtleſs been very great.

WITH us in the *Weſt* (from whence this is wrote,) every Ploughman and Shepherd is able to make good Reſervoirs or Ponds for holding of Water; Clay alſo, that is good, abounding much with us. The Method of doing which I ſhall lay down by-and-by, when I have ſaid ſomething as to the *Profile* and Diſpoſition of theſe Reſervoirs, and the Manner how they are built in ſeveral Places.

AS to the Form of which theſe Reſervoirs or Baſins are made, it is of no great Conſequence, though a Square or an Oblong are as good Figures as any: And as to the Extent, it is undoubtedly according to the Quantity of Water which is requir'd, 100, 150, or 200 Foot ſquare, being ſufficient in moſt Caſes; though for large Cities, Towns, &c. 300, 400, or 500, is not more than enough: But the deeper they are, the better; contrary to the Practice of ſome that I have lately obſerv'd, which have not been above three or four Foot deep, when I judge they ought to be from ſeven or eight to ten or twelve Foot deep, that the Water may ſettle the better; and the Bottom ſhould be fill'd two or three Foot high, with large Gravel-Pebbles; by which Means the Sediment will have Room to lodge and ſettle therein, and this Bottom ſhould be well Clayed, and lie lower by three or four Foot than the Bottom of the Aqueduct that brings the Water in, for the Purpoſes before mentioned.

IF the Reſervoir be but ſmall, as fifteen or twenty Foot over, then I would adviſe the Section of it to be made Coniodical; becauſe by this Shape it will happen, that the Preſſure of the Water on the Pipe of Conduct will be regular and uniform, from the Beginning to the End of the going out of the Water.

By this Conoidal Form it is, that *Archimedes*, in ſome excellent Propoſitions of his, in his two Books *de Inſidentibus Humido*, demonſtrates the Gravitation or Preſſure of Fluids one upon another, which was alſo followed by *Gallileo*, *Torricelli*, and others.

To this Purpoſe alſo, *Marriotte*, in his Rules for the Meaſuring of ſpouting Waters, through Adjutages of different Bores, *Diſcourſe* III. *Pag.* 185. of the *Engliſh* Edition of his Hydroſtaticks, ſets down a very curious Problem, which he ſays *Torricelli* has not undertaken to reſolve, though he propos'd it. This Problem is, to find a Veſſel of ſuch a Figure, that being pierc'd at the Bottom with a ſmall Hole (when the Veſſel is ſmall, but larger as a Veſſel or Reſervoir is larger,) that the Water ſhould go out, its upper Surface deſcending from equal Heights in equal Times.

Let it be a Conoidal Figure, *Fig.* 1. *Tab. ſeq.* where B L is to B N as the Square ſquared of N O, and B N to B H as the Square ſquared of N O to the Square ſquared of H K, and ſo on: The Water will deſcend from A D C in an uniform Manner, till it comes to the Hole at B. For let B P be the mean Proportional betwixt B D and B H, ſince the Square ſquared of K H and of D C are to each other as the Heights B H, B D, the Squares of H K, D C, will be in a ſubduplicate *Ratio* of B H to B D; or as the Heights B P, B D. But the Velocity of the Water that goes out at B, by Reaſon of the Preſſure of the Height B D, is to the Velocity of that which goes out by Reaſon of the Preſſure of the Height B H in a ſubduplicate *Ratio* of B D to B H, that is to ſay, as B P to B D: Therefore the Velocity of the Water deſcending from H, is to the Velocity of the Water deſcending from D, as the Square of H K to the Square of D C: But the circular Surface of the Water at H is to the circular Surface of the Water at D, as the Square of H K to the Square of D C; therefore they will deſcend and run out one as faſt the other: And if the Surface A D C runs out in a ſecond, the Surface G H K will run out in a ſecond likewiſe, ſince the Quantities are as the Velocities.

The ſame Thing will happen to the other Surfaces at E and F, &c. but the Hole muſt in all minute Caſes be very ſmall, that no conſiderable Acceleration may be made, and that the Water may not go throughout the Hole ſenſibly, but in a Proportion to the Weight. A Veſſel of this Model, ſays the ingenious *Marriotte*, may ſerve for a Clepſydra or Water-Clock; and, I add, for any Reſervoir for ſupplying and playing Fountains or any other Water-Works in Gardens, or for the regular Diſtribution of Water for the Uſe of any City or Town; and is ſtill the more uſeful and proper to be made, when the Spring riſes near the Place where the Water is to be us'd, as does that of *Longleat* in *Wiltſhire*, the Seat of the Right Honourable the Lord Viſcount *Weymouth*, and other Places.

The Section or *Profile* of a Reſervoir being thus ſet down, pertaining as it does to thoſe only which are narrow and deep, as all Reſervoirs muſt be, which are made on the Side of a Hills and near a Spring, it will be requiſite that I inform my Reader, that the Structure of ſuch Reſervoir or Ciſtern be of Stone or Brick, ſince there is no working of Clay to ſtand in ſo perpendicular a Manner as the Figure deſcribes. But when we come to make Reſervoirs of that great Extent which they often are, this *Profile* or Section can be of no great Uſe, nor can the Figure of it be followed.

It is more to the Purpoſe then, that we lay down a ſhort Account of thoſe Rules which are neceſſary to be obſerv'd in the *Profile* and Diſpoſition of Reſervoirs that are made of Clay, and the Methods of Digging, Picking, Cleanſing, Beating, or Ramming of that uſeful Material.

The Slopes then on each Side, and at the Ends of any Reſervoir, if the ſame be made of Clay, which is by much the cheapeſt of any Material wherewith Reſervoirs or Ponds are uſually made, ſhould be at leaſt three Foot horizontal to one Foot perpendicular, that they may ſtand well, and not be ſo ſubject to Mouldering: So that if a Reſervoir be ſeven or eight Foot deep, which I would by all means adviſe in Works of this Kind, the Baſis of the Slope ought to be twenty eight, thirty, or thirty two Foot; the *Profile* or Section of which ſee *Fig.* 2. *Tab. ſeq.* and the Banks ſhould be freed of all Trees and other Incumbrances, which are apt to tear the Banks by the Rocking and Blowing of the Winds. As to what relates to the Time of making Reſervoirs, the Digging, Picking, Cleanſing, and Ramming of the Clay, take the following Rules:

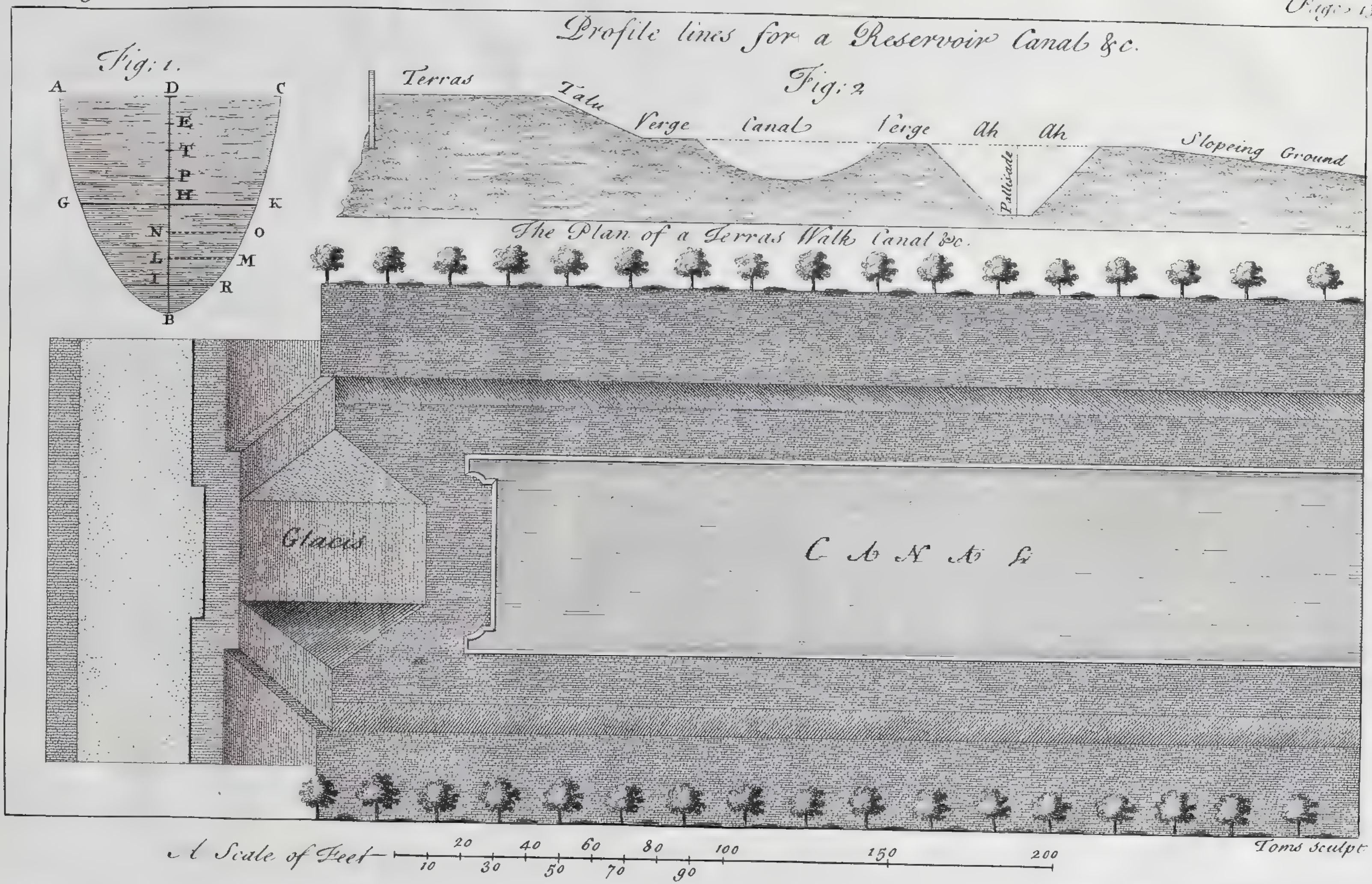
The beſt and moſt proper Seaſon for digging of Clay and making Reſervoirs, and other Water-Works of this Kind, is generally about *Michaelmas*, after the firſt Rains have fallen; for then the Clay works well, and the Seaſon is coming on to be cool, and in ſuch a Manner that you may expect the Rains will fill your Work, in caſe your Supply ſhould be precarious.

The Shape of the Reſervoir or Pond being firſt made, you are to dig your Clay, and uſe it immediately; otherwiſe you will be oblig'd to water it, which will ſpoil it: And you ſhould be very careful to pick it clean of all large Stones, Sand-Holes, and Veins, and to throw out all ſuch Parts of it as any way degenerates from the general Maſs or Vein of Clay you dig.

Your ſtrong reddiſh or yellow Clays are accounted beſt; but there are white and blue Clays which are as tenacious as any of the former, though they may not be ſo ductile, nor work ſo well. The Weſt-Country Pond-men, as I have very lately obſerved, chuſe that Sort of Clay that has ſome ſmall Parts of Pebbles or Gravel in it; becauſe, ſay they, it rams the better. Clays run often in Veins; but if you dig it in Pits where it lies deep, the deeper you generally go, the better and ſtronger the Clay is.

Assoon as ever you have found that which is good, and it is dug, carry it to the Place where there is Occaſion for it, and uſe it immediately, before the Sun and Air has harden'd it ſo that it won't work: But if you have not an immediate Occaſion for it, cover it

over


Profile lines for a Reservoir Canal &c.
Fig: 1.
A
D
C
E
T
P
H
G
K
N
O
L
M
I
R
B
Fig: 2
Terras
Talu
Verge
Canal
Verge
Ah
Ah
Pallisade
Slopeing Ground
The Plan of a Terras Walk Canal &c.
Glacis
C A N A L
A Scale of Feet
10 20 30 40 50 60 70 80 90 100 150 200
Toms sculpt

over with long moiſt Horſe-Dung, or wet Hay, or Thatch; and when you bring it to the Place where it is to be uſed, begin in the very Middle or Center of the Bottom of the Pond, where you are to lay it thicker than ordinary; and ſo work every Way from it, treading and beating it well as you go with Inſtruments, which I ſhall give a more large Account of by-and-by.

It has been much diſputed amongſt Workmen, and there is a Kind of Uncertainty in all the Books I have read on this Subject, how thick Clay ſhould be laid, without telling us in what Manner it ought to be wrought, ſome allowing a Foot, ſome a Foot and a half, and others more, for the Thickneſs thereof: Nor do they mention what is practis'd amongſt Workmen, namely, the laying it not all at once, but in two diſtinct Layers of about ſix or eight Inches thick at moſt.

When you have begun in the very Center or Middle of the Reſervoir, as above mention'd, and laid it there about ſix or eight Inches thick, you may throw the Horſeheads or large Spits of Clay together, juſt as they are dug out of the Pit, only picking out the large Stones, or any Veins of Sand you can find therein; having always at hand a large heavy Beater or Beetle, ſuch a one as you cleave Wood withal, and with that work it well together; and having done a Yard or two at a Time in that Manner, you are to have ready at hand another flat Beater, ſuch as thoſe you beat Graſs with; or, which is better, let it be made in the Manner which a hard Bruſh is made, wherewith Maid-Servants rub their Rooms, but a ſtronger Handle, and in the Head thereof fix four or five ſtrong Iron Teeth, which will, as it were, cut or ſcratch a-croſs the Joints, to prevent any open Chaſm or Crack that would otherwiſe be there: Which done, take ſuch a Rammer as Paviors uſe, (though it need not be quite ſo heavy,) and ſmooth it over. This done, you had beſt lay a little long Dung, Hay, or Thatch, as before, to keep the Clay from cracking, till you come on with your ſecond Coat.

The firſt Coat being laid quite over in the Manner thus directed, you are to ſtrow ſome ſlack'd Lime all over it; for this won't only corroborate, and make the Clay grow hard and dry, and, as it were, almoſt impenetrable, but it will prevent the Worms from working in the Clay, as our Pond-Makers in the *Weſt* tell me.

This done, you are to begin again in the Bottom the ſame Thickneſs as you did at firſt, and work every Way from the Center, proceeding in the ſame Manner as you did before, taking Care, above all, to break, join, or cloſe the Clay well, as by the Inſtrument with Teeth you may very well do; and you will have this Certainty in doing the Work

over again, that if there ſhould be the leaſt Crack or Perforation in one Layer, the other coming over it again will fill it up, and ſupply the Place that may be occaſion'd by ſuch a Default.

Upon the upper Coat of all you are to put a little more Lime and Chalk mix'd together, and ram it on three or four Inches thick; by which Means it will incorporate into the Clay, and make, as it were, one ſolid Body, which you may pitch with Flint Stones, if there be Occaſion, that is, if Cattle have Egreſs and Regreſs thereto for Drinking. However, all Reſervoirs, if they are not Wharfed with Wood, Brick, or Stone, (which I would not adviſe as being very expenſive) ought to be pitch'd a Foot or two below the high Water-Mark, to prevent the Waſhing away of the Clay on the Sides of the Reſervoir; as alſo the Working of Moles, Mice, and other Vermin, that ſpoil the Banks.

There are, who are ſo exact as to lay a third Laying or Coat of Clay over the other two, and of the ſame Thickneſs, *viz.* ſix or eight Inches: And this is, indeed, a very commendable Way, and very neceſſary in Grounds that are of a dry, gravelly, husky Nature. One of this Kind I remember to have been concern'd at my firſt ſetting out in Pond-Work in *Eſſex*, which ran out ſo faſt till the Pores of the Earth were ſated, that an Engine which was three Days and Nights employ'd, could ſcarce keep it full, ſo that certainly three Times Claying is much more ſecure, and the Expence not much larger. The Digging and Claying of a Reſervoir or Canal twice is worth about twelve Pence a Yard ſuperfical; and if they were to be Clayed a third Time, it would not be above three Pence a Yard more: But then all the Clay muſt be brought to the Place, the Carriage of it being ſo uncertain that no Undertaker can well tell how to do it. But I know ſome of our Head Weſt-Country Pond-Men have had eighteen Pence a Yard for two Layers of Clay only.

It has been already adviſed that the Bottom ſhould be fill'd with Gravel, Pebbles, or the like; which lying upon the Chalk, will contract the Sediment and Slime, which naturally comes along with Water, and will make it look more pure and clear.

And I have farther very lately obſerved, that the Pond-Men in the *Weſt* do not pitch their Fiſh-Ponds ſo much as they uſed to do heretofore, but lay ſix or eight Inches of Chalk upon the Clay, which is better for all Sorts of Fiſh than pitching: The Fiſh-Ponds on *Black-Heath* are, as I am told, bottom'd with Heath.

I have alſo already mention'd the Method the Ancients us'd in having Ciſterns one within, and often below one another, that Water which was foul, might be ſtrain'd through, and leave its Sediment

in its Paſſage through them; but what I would recommend in this caſe, and what is much cheaper, is Hills of the fineſt Sand you can conveniently procure, ſuch as in its own Nature it is not ſubject to be dirty. When the Water comes in, then let it be at one End, having three or four of theſe Sand-Banks lying a-croſs our Reſervoir, give the Water Time to filtre through, and let the Pipe which is to ſupply your Fountains lay at the farther End, ſo may you expect to have your Water clear, and there Sand-Banks ſhould lie and be above the Surface of the Waer, when it is higheſt of all.

I HAVE already, I think, mentiond that about *Michaelmas* is the moſt proper Time for ſuch Works, in as much as the Weather is then the cooleſt, and that there is, in Caſe of any dubious Want of Water, ſufficient Time for the filling the Pond; but the Winter or Spring, or indeed any other Part of the Year will do as well, provided you dig your Clay, and uſe it immediately, and that you have a River, a ſtrong Spring, or ſome very good Engine to fill it: But you muſt beware of Froſts, and of the drying cutting Winds of *March*, which do more Hurt to new Ponds, than any other Variation or Change of Weather does. What relates to the making Reſervoirs for Ponds with Brick or Stone, I ſhall ſet down elſewhere.

NOTES

NOTES upon BOOK I.

CHAP. I. PAGE 6. LINE 15.

AND *that the Architect has allowed five Foot in a Mile for the Deſcent or Current of the Water.* Upon a ſecond Reviſal of this Paſſage, and the 2d Edition of Mr. *Addiſon*'s *Travels*, I find it is five Foot and an half in a Mile Fall, that the *Romans* allowed for the Conveyance of their Water in their Aqueducts and encloſed Pipes; which is nearly agreeable to what has been allowed in the Chapters going before; eſpecially in all great Lengths, where the Friction is conſiderable. And this Paſſage of Mr. *Addiſon*'s confirms an Obſervation made in this Treatiſe, That it was by this Means, *viz. by going back a good Way, that the* Romans *could take up their Water from what Height they pleaſed, without the Expence of ſuch an Engine as* Marli.

Chap. I. p. 10. l. 41. *It muſt be confeſſed that we are not yet arrived to that Grandeur in our Garden Waterworks in* England, *as they are in* France *or* Italy, &c. Mr. *Addiſon*, whoſe Remarks on Men and Things has been ſo juſtly admired, ſays, *p.* 45. of the late Edition of his *Travels*, that though the *Italians* fall ſhort of the *French* in their Gardens, yet that it muſt be ſaid, to the Honour of the *Italians*, that the *French* firſt took from them the Plans of their Gardens, as well as Waterworks; ſo that the ſurpaſſing of them at preſent is rather to be attributed to the Greatneſs of their Riches, than the Excellence of their Taſte. The Caſcades of *Italy*, which are generally natural, or contrived agreeable to it, are certainly ſome of the nobleſt in the World. The *Roſea Rura Velini*, which *Virgil* mentions in his 7th *Æneid*, is, according to Mr. *Addiſon*, a wonderful Thing: " The
" Channel of the River lies high, and is
" ſhaded on all Sides of it by a green Fo-
" reſt, made up of ſeveral Kinds of Trees,
" that preſerve their Verdure all the Year.
" The neighbouring Mountains are cover'd
" with them; and, by Reaſon of their
" Height, are more expoſed to the Dews
" and drizzling Rains, than any of the ad-
" jacent Parts, which gave Occaſion to the
" Poet's *Roſea Rura* (or dewy Country.)
" The River, ſays our oft-quoted Travel-
" ler, runs extreamly rapid before its Fall,
" and ruſhes down a Precipice of an hun-
" dred Yards high, throwing itſelf in the
" Hollows of a Rock, the Bottom of which
" it is impoſſible to ſee. In this, ſays our
" learned Obſervator, there is ſomething
" more aſtoniſhing, than in all the Water-
" works of *Verſailles.*"

Of this Caſcade, which is not far off from that Part of *Italy*, which has been called *Italiæ Meditullium*, which Mr. *Addiſon* judges to be the Gulph thro' which *Virgil*'s *Alecto* ſhoots herſelf into Hell. *Virgil* thus ſings—

———denſis hunc frondibus Atrum
Urget utrinq; latus Nemoris, Medioq; fragoſus
Dat Sanitum Saxis & torto vortice torrens:
Hic Specus horrendum & Sævi ſpiracula Ditis
Monſtrantur, ruptoq; ingens Acheronte vorago
Peſtiferas aperit fauces, queis Condita Errinys
Inviſum Numen terras, Cœlumque lævabat.

Thus Englifh'd by *Dryden:*

————————on either Side
Thick Forefts the forbidden Entrance hide:
Full in the Center of the Sacred Wood
An Arm arifeth of the Stygian Flood;
Which falling from on high, with bellowing
Sound,
Whirls the black Waves and rattling Stones
around:
Here *Pluto* pants for Breath from out his Cell,
And opens wide the grinning Jaws of Hell;
To this infernal Gate the Fury flies,
Here hides her hated Head, and frees the
labouring Skies.

To conclude this Note, Mr. *Addifon* is fo wonderful in his Defcription of Rivers, Rural Scenes, and Falls of Water, that I cannot but quote him in the noble Defcription he gives, from his beloved Poet *Virgil*, of the Lake *Benacus*, now *Lago di Garda.*

Adde lacus tantos te Lari Maxime, teque
Fluctibus & fremitu affurgens, Benace, Marius.

Here vex'd with Winter Storms *Benacus*
raves,
Confus'd with working Sands and rolling
Waves;
Rough and tumultuous like a Sea it lies,
So loud the Tempeft roars, fo high the Bil-
lows rife.

At the lower End of this Lake lies the *Mincio*; of which *Virgil. Georg*. 3. thus:

————*Tardis ingens ubi flexibus errat*
Mincius & tenera prælexit Arundine ripas.

Thus Englifhed by *Dryden.*

Where the flow *Mincius* through the Valley
ftrays:
Where cooling ftreams invite the Flocks to
drink,
And Reeds defend the winding Waters
Brink.

Claudian's *Larius* is by Mr. *Addifon* fuppofed to be an Imitation of *Virgil*'s *Benacus.*

———— *Umbrofa veftit qua Littus Olivâ*
Larius & dulci mentitur Nerea fluctu.
De Bell. Get.

The *Larius* here with Groves of Olives
crown'd,
An Ocean of frefh Water fpreads around.
Thus far Mr. *Addifon.*

Chap. I. Pag. 11. *The* Villa de Medicis, *with its Waterworks*; *the Cafcade of the* Feverone, *with the famous Falls of the* Frefcati, &c.

I muft own myfelf a little concerned, that two fuch great Authors as Mr. *Addifon* and Mr. *Miffon*, fhould have fuch different Ideas of the Waterworks of *Italy*, as they have: The firft fpeaks of them in the loftieft Manner; but the laft, as it were, with Contempt, in refpect to thofe of *Verfailles*; but as this might proceed from the particular Attachment that the latter had to the Intereft and Glory of his Country, his Partiality may be in fome meafure excufed; fince, by all the Prints I have feen, it appears, (whatever Efteem we put on thofe of *France*) that the Waterworks of *Italy* are much more rural and grotefque, than thofe of *France.*

Miffon, Vol. II. p. 63. fays, He is forry that he cannot relate fuch Wonders of the *Tivoli* and *Frefcati* as his Friends might feem to expect: And a little after, that the Gardens and Waterworks of the *Belvedere*, the *Villa Ludovifia*, &c. deferve to be compared to *Verfailles*, as *Frefcati* to *Rome*, or two or three Trees to a fine Landskip; though he gives a pretty good Encomium on the Cafcade of the *Villa Ludovifia.* And *p.* 66. he tells us, that the Waterworks of *Verfailles* (an extravagant Way of comparing Things) exceed a thoufand Times thofe of *Tivoli.*

The Cafcade of the *Teverone*, or the ancient *Anio*, he fays, is the moft remarkable Thing in this little Town; that the River forms a pleafant Sheet; but the Fall (though *Horace* and *Silius Italicus* call it *Præceps Anienus*) is not high; and indeed by the Prints I have feen, it is not above four or five Yards at moft; near to which is that made by the late Duke of *Kingfton* at *Thoresby*, *Nottinghamfhire*, &c.

But although I have been fomewhat difpleas'd with Mr. *Miffon* for the contemptuous Account he gives of the Waterworks of *Italy* (in Oppofition to Mr. *Addifon*, who will always be the Favourite of the *Englifh* Nation, yet I could not but like the Defcription he has given of the Fall of the River

Velino,

Velino, which he paints, if poſſible, in ſtronger Terms than Mr. *Addiſon* himſelf has done; for which ſee *p.* 363, 364, and 365, *Vol.* I. *Part* 2. of *Miſſon*'s *New Voyage to* Italy: All which may be ſumm'd up in the Account that *Athanaſius Kircher*, in his Treatiſe call'd *Mundus Subteraneus*, *Lib.* 2. *Paragr.* 4. *Pag.* 115. *Col.* 1. ſets down. Let me uſe his own Words.

Fluvius ſummo impetu in modum Areas ruens in profundum voraginem, Altitudine ccc *circiter pedum uti ex Dimenſione Rupis à me facta patuit. Examinatis itaque omnibus inſtitutio meo opportunis Catadupæ circumſtantiis inter amniam reverſus.*

I might (from Authors who have wrote of the *Eaſt* and *Weſt Indies*, and other Parts) have added what they have ſaid of ſuch precipitate Cataracts of Water, but that I fear I ſhall thereby tire my Reader.

The *Nile* (as *Varenius* in his *Geograph. General*, *Cap.* xvi. *Prop.* x. has it) falls from between two Mountains ſo great a Height, and with ſuch Force, that it is ſaid to make the Inhabitants deaf; and the *Wolgda* (not the *Wolga*) a ſmall River of *Muſcovy*, has two large Cataracts near *Ladoga*. The River in the Kingdom of *Congo* has one, where the Water falls from the Top of a high Mountain; as has the *Rhine* near *Bilefelda* and *Scaufhauſen:* Nor are we altogether wanting of our natural Falls of Water in *Great Britain*; ſince I am well inform'd by the ingenious Sir *Robert Cotton*, that there is ſomewhere in *Wales* a Cataract, or Fall of Water, of a Height equal, if not exceeding any yet mention'd, that runs down with continual Violence.

Chap. II. Pag. 15. Line 1. *For that of* Ariſtotle *and his Followers*, &c. This Opinion of *Ariſtotle* and his Followers is related at large by *Varenius*, *pag.* 224. of his *Geograph. General.* in the following Manner. Ariſtotelici *ſequuntur opinionem Præceptoris ſui* Ariſtotelis, *quod aqua fontium generetur ex Aere in terræ viſceribus contento. Rationes adducit has:* 1 *Ex aere ſupra terram exiſtente aquæ generantur, pluviæ nimirum: itaquæ cum in terræ viſceribus & aer ſit & eadem condenſationis cauſa, nempe frigus, ideo abſurdum eſſe dicit, ſi quis non putet ibi quoque ex aere aquam fieri.* 2. *Experientia teſtatur. quod in terra grandiores guttæ ex parvis factæ ſtillent, & ideo fluviorum principia eſſe quaſdam veluti ſcaturigines aquarum, quæ in unam aliquam terræ partem concurrant. Ideo enim, qui aqua ductus ſtruunt, ſcrobibus atque cuniculis aquam deducere, tanquam ab excelſis ſudante terra ſolent.* 3 *Quia plurimi fontes, & quidem maximorum fluviorum in locis montanis reperiuntur, pauci in locis planis, &c.* For which alſo ſee *Ariſtotle*'s firſt Book of Meteors, *Chap.* 11.

Chap. II. Pag. 15. Line 4. *As a learned Phyſician, in a Manuſcript*, &c. This Phyſician, who has quoted the Opinion of *Aquinas*, *Scaliger*, *Faber*, *&c.* was the learned Dr. *Chamberlayne* of *Shaftsbury*, *Dorſetſhire*, who has left in the Hands of his Daughter, Mrs. *Mary Climpſon* of *Hungerford*, *Berkſhire*, a large Volume in Writing of conjectural Philoſophy, in which he appears to reaſon excellently well on all thoſe difficult Points.

Chap. II. Pag. 15. Line 20. Faber *from the Attraction of all Waters by the North Pole*, &c. This Opinion had its Riſe, in all probability, from the general Eruption of Springs out of the North, rather than out of the South Sides of Hills, as is obvious to any (even the moſt incurious) Obſerver. Thus *Varenius* ſays of them, *averſi ſunt ſolis curſui*; and juſt after, *ipſique montes ſuas habent umbras obſtantes, ut radii Solis non directè perveniant ad terram, nec poſſint humores exſugere.* Prop. xxii. Cap. 16.

Chap. II. Pag. 16. Line 10. *Whence, according to the Opinion of ſome of the beſt Philoſophers, both ancient and modern, it had its firſt Riſe.* In the Solution of this, ſee *Varenius* alſo, who, from many weighty Reaſons, ſome of which follow, concludes, *Quod terram, quicquid aquarum ex oſtiis fluviorum in mare emiſit, rurſus accipere. Occulto enim itinere maris aquam ſubire terras, & in tranſitu per multiplices anfractus terrarum verberatum & per arenas atque argillam colatum deponere ſalſedinem & amaritudinem, & ſic in ſinceram aquam tranſire.* And, ſays he, this I believe to be true, though I don't altogether deny other Cauſes; for that above a thouſand Rivers empty themſelves into the Sea; and, to give it in his own his Words, *Rationes ſunt hæ:* 1. *Quia plures quam mille fluvii in mare ſe exonerant, & majores ex illis tanta copia, ut aqua illa, quam per totum annum emittunt in mare, ſuperet totum* Tellurem, *ſicut* Wolga *in mare* Caſpium, *& alii. Itaque fieri aliter nequit, quin ex mari aqua in plurima* Telluris *loca, & uſque ad fluviorum*

fluviorum fontes emittatur. Nisi enim hoc fieret, ne cogitari quidem poteſt, quomodo mare non augeatur in immenſum, vel cur fontes non deſinant emittere aquam. Neque dicas, vapores tam multos è mari elevari, quàm aquæ mare acceperit à fluviis, &c.

Chap. II. Pag. 16. Line 27. *Tho' thoſe Veins, Channels, and Ducts of Earth*, &c. That there are ſuch Veins is evident from all heterogeneous and different Bodies, ſuch as Scollop, Muſſel, and Oyſter-Shells, which are found in the Bowels of the Earth very diſtant from the Sea. Of the ſame Kind alſo is that Maſt, which was (as Dr. *Plott*, *pag*. 108. relates) dug out of the Top of an exceeding high Mountain in *Greenland* with a Pulley join'd to it; but this is not to be compared to what *Baptiſta Fulgoſa*, *Ludovico Moſcelli*, and *Theodoro Moretto*, *Anno* 1460. relates of a Pit near *Verona*, that was fifty Fathom deep, out of which was dug a whole Veſſel, with Anchors and broken Maſts, and in which were alſo the Corps of forty Seamen and others.

Now, tho' ſome of our ingenious Theoriſts, in the Account they give of this heterogeneous Mixture in the Bowels of the Earth, attribute all this to the Deluge, which they ſay diſſolv'd all the World into a Kind of a Pap; and that every Thing then ſunk deeper or ſhallower, according to its ſpecifick Gravity, and ſo Scollop and other Shells may ſink with them; yet this Deluge was ſo very long ago, that it was improbable theſe Things ſhould remain ſo long unconſumed: The Account of the Ship eſpecially; which is atteſted by many grave and ſerious People, could not be then, in all probability, ſunk; becauſe Navigation was not then known, nor 'till the Ark was made, no Veſſel of that Kind was ever ſeen; ſo that, in all probability, the Veſſel here mentioned was drove up through the Syrtes or Quickſands of the proximate Shores, into theſe Veins and Hollows of the Earth, as it is related by *Andrew Moralis*, *Decad*. 7. *cap*. 8. of the Gulph of *Charybdis*, near the *Sicilian* Sea, over-againſt *Sylla*, where Abundance of all Kind of Things are found; the Water there whirling about with ſuch a Force, that tho' they endeavoured all they could, yet they could hardly keep the Ship they were in from being ſwallowed up. And of this Kind Dr. *Plott* (*pag*. 111.) produces a great many more, amongſt the Iſlands of *Mosko*, *Weroe*, *Rooſt*, and *Lonfondon*, in the *Norway* Shores, call'd by ſome the *Monsk:* This *Homer* calls Ὀμφαλος Λαλάσσης; *Umbilicus Maris*, by *Paulus Diaconus*; *Anhelitus Mundi*, by *Mela*; *Nares Mundi*, by *Solinus*; *Acheron*, by *Suidas*; Τάρταρος, by *Pluto* and *Ariſtotle*; one of which, as *Abraham Ortelius* in his *Geographical Treatiſe*, under the Word *Umbilicus*, ſays, was forty Miles in Circumference, and ſo ſaperfuſe in the Summer, that it appeared like a Sea itſelf, and which, with a horrible Noiſe, at once overwhelm'd Ships, and whatever elſe came thereinto.

Chap. II. Pag. 16. Line 36. — *That give another Reaſon for their Origin and Riſe, attributing it to Vapours, and not Air*, &c. Of an Opinion ſomething of this Kind was *Cardanus*, as the ſame *Varenius*, *pag*. 221. of his oft-quoted Treatiſe ſets down in the following Words:

Cardanus *cum aliis cenſet, aquam fontium fieri à rivulis, quæ ex aqueis vaporibus tam intra quam extra terram exiſtentibus & condenſatis generati ſunt, ſed fontes ſolos vix efficere fluvios, niſi pluviæ vel reſolutæ nives accedent. Rationes ejus ſunt.* 1. *Si montes mane inviſas, humidos invenies.* 2. *Fluvii matutino tempore excreſcunt & quidem eo magis, qui fonti proprior pars ejus ſit.*

But *Varenius* himſelf ſoon turns the Scale againſt both theſe Philoſophers, by ſaying, *Verum perpetuus & conſtans proſilientis ex fontibus aquæ impetus non videtur à tam imbecilli cauſa & inconſtante ortu habere. Neque differt hæc* Cardani *ſententia multum ab* Ariſtotelica, *niſi quod* Ariſtoteles *aerem cum generatione*, Cardanus *vapores ſine generatione ponit cauſam fontium, & vero exigua eſt inter aerem & vapores differentia.* See *Lib.* 1. *Prop*. v. *Art*. 4. of *Varenius*'s *Geography* beforeſaid.

Chap. II. Pag. 23. Line 1. *That in a Year there might commonly fall in Rain-Water to the Height of* 17 *Inches*. The different Depths of Rain, one Year with another, if it was to ſtagnate on the Earth, the curious and inquiſitive Mr. *Derham* has, in the *Tranſactions of the Royal Society*, and in his Notes

on his *Physico-Theology*, *pag*. 23. thus stated. At *Townly* in *Lancashire* 42 Inches and an half; at *Upminster* in *Essex* 19 Inches and a Quarter; at *Zurich* in *Switzerland* 32 Inches and a Quarter; at *Paris* in *France* 19 Inches; and at *Lisle* in *Flanders* 24 Inches.

Something agreeable to this are the Observations of an anonymous *French* Author, which Dr. *Plott*, *pag*. 62. of his *Teutamen de Origine*, *&c*. so often mentioned, who took the Course of the Sun from the Head of that River at *Ainay le Duc*, where another small River joins it; and found *(communibus annis)* as himself expresses it, that the Rain-Water amounted to 19:2 In. Lines $\frac{1}{3}$ *d*. from which he pronounced, that it equall'd 280899942 Measures *French*, which *French* Measure is as 83 to 68 Hogsheads and 42 Gallons *English* of Beer, or Ale, lawfully stamp'd; for a *French* Measure, according to *Plott*, contains 16777 $\frac{216}{1000}$ cubick Inches *English* Measure, which makes 59 $\frac{491}{1000}$ Gall. of a Gallon, which is near 59 Gallons and a half: So that a *French* Pipe scarce contains $\frac{5}{6}$ of an *English* one.

This being premised, if one cubick Inch of Water will (according to that Author) produce 83 Hogsheads *French*, or 68 *English* in a Day; then 1200 Cube Inches, which is the Measure of the River of the *Gobelines* near *Versailles*, will produce 99600 Measures; and, in one Year, which is near 366 Days, it will give 36453600 Hogsheads *French*; which, if you substract from 280899942 Hogsheads, which fall annually in the Conservatory, or Tract of Land, there will remain 244446342 Hodsheads; which is six or seven Times as much as is taken in for the Supply of the River; which he supposes is more than enough for the Nourishment of Plants, the Supply of Vapours, the Exercise of Rivers, *&c*. For this see his Treatise *De l'Origine des Fountains*, *seconde Partie*, *a Page* 189 *ad Pag*. 207. Tho' this is found to be dificient at *Willow-Bridge*, which is elsewhere intimated.

To proceed, *Jo. Baptist Ricciolus*, in his *Almegisto Novo*, *Lib*. 2. *Cap*. 13. tells us, That the *Eridanus*, or *Padus* in *Italy*, which is 1000 Paces wide, and 15 Foot, or 3 Paces in Depth, 18000000 cubick Paces of Water every Hour, that is, 432000000 in a Day, and 1552000000 in a Year. And if the *Padus* in *Italy* affords so much, the River of *St. Lawrence*, which is 60 Times broader, and, in all Appearance, much deeper, must produce 93312000000 in a Year of cubick Paces of Water: all which I mention because I would state the Case as fairly as I possibly can.

To illustrate this, I beg Leave to add an Account which I find in the Histories of *England*, by which it is (I think) apparent, that Rains can have little or no Manner of Effect in the Supply of Springs: For how else should it happen, that the *Trent*, a large River which rises in the County of *Stafford*, (as *Knighton*, in his Treatise *de Eventibus Angliæ*, *Lib*. 2. sets down) which was observed at *Nottingham*, *Anno* 1110, in the Reign of *Henry* I. that the whole River was dry of a sudden, from early in the Morning to about Three of the Clock in the Afternoon. I say what else could it be from, but that the subterraneous Ducts, which were to supply the Springs, (for there had been no Droughts that any Body had observed) were by some fortuitous Confusion so disorder'd, that they could not supply any more Water, until those Confusions, or the Obstacles that hindered it, were removed by proper Powers, or till the Waters should seek another Way. Four Years after that, (*viz*.) in the Ides of *Oct*. 1114, as *Simon* of *Durham* and *John* of *Brompton* have deliver'd it down, the *Vaga*, or *Medway*, was so dry for some Miles, that for two Days it would not carry even the smallest Boat; for which see *Simon* of *Durham*'s *De Rebus Gestis*, *Ang*. and *Chronicon* in *Anno* 1114. The same Thing also writes *Matthew Paris* of the River *Thames*, which was so stopped for two Days, that the Sea also retracted, or shrunk back from the Shore; and other Authors add, that Boys could pass on Foot from the *Tower* to *London Bridge*; and even under the Bridge itself were scarce up to the Knees. Neither, in the mean Time, do the Writers speak of any Want of Showers which cause these Events. This one indeed might be the Reason, that the Tides had first failed sending up their Supply, and then of Course the Springs must fail.

Chap.

Chap. II. *Pag.* 28. *Line* 28. *An. Errata: Read*, There are ſmall Veins of Water, which belong, and ſend the Water to thoſe which lie *lower* (*inſtead of* higher).

Chap. II. *Pag.* 29. *Line* 18. *Read*, And don't contribute much (if at all) to the Increaſe of Perennial Springs.

Chap. II. Pag. 29. Line 30. ——— *they would be obliged to go above a hundred Yards deep before they come to Water.* I add to this an Obſervation which the Reverend and Learned Mr. *Derham* has collected from ſome skillful Workmen, whoſe Buſineſs it was to dig Wells in *Eſſex:* The Ground being a Clay, after they had dug fifty Foot deep, the Man in the Well obſerved the clayey Bottom to ſwell, and begin to ſend out Water; and ſtamping with his Foot to ſtop the Water, he made Way for ſo ſudden and forcible Flux thereof, that before he could get into his Bucket, he was above his Waſte in Water; which ſoon aſcended to ſeventeen Foot higher, and there ſtay'd. And altho' they often, with great Labour, endeavoured to empty the Well, in order to finiſh their Work. yet they could never do it, but were forced to leave it as it was. *Vid.* the Reverend Mr. *Derham*'s *Phyſico-Theology*, *cap.* 24. *pag.* 77.

And from hence I would obſerve, that if Rains, &c. were the Cauſe of this violent Eruption of Springs, they would lie above the Beds and Strata of the Clay, rather than under them, (as indeed all Land-Springs, which have their Original from Rains, yet ſeldom or never flow, do); ſo that it is plain they come from a deeper Cauſe, (*viz.*) from ſome ſubterraneous Tubes, out of which being releas'd, by digging away the Strata and Beds of Clay above them, the Flux of Water is ſo immediate and large.

Chap. II. Pag. 30. Line 39. *And if it be made appear*, (*as I think it is*) *that cold Waters are not produced by Rains*, &c. Our oft-quoted *Varenius*, *Lib.* 1. *Cap.* 17. *Prop.* xi. tells us of a Fountain, not far from *Vienna*, of that Coldneſs, that it ſwells the very Mouths of thoſe that drink it; neither can a Man hold his Hand in it; that it is not diminiſhed, when the Water is endeavoured to be drawn out, nor increaſed, when there is any put into it: And that there are in *Troglodidiente Arabia* or *Æthiopia*, ſome Fountains extreamly cold, though it be in the Middle of Summer; and that there are in *Stiria*, four Miles from *Gratz*, or *Gretz*, Fountains ſo cold at the Bottom, that no Body can draw Water out of them. Now how this ſhould be, unleſs theſe Waters were detach'd from the Bowels of the Earth, where there is a Mixture of Nitre and Alum, as alſo of Mercury, Iron, &c. is hard to conceive. And that this (ſays my ingenious and learned Author) was the Occaſion of it, is certain, not only from the foregoing Cauſes, but from the Depths of the Spring; and for the Defect of the Sun's Beams, and of ſubterraneous ſulphureous Heat.

To proceed, in the Words of my Author, *Sunt etiam fontes quidam, qui alternatim ſunt calidi & frigidi in* Catalonia *lacus, & fons* Salpola *hyeme tepidus, æſtate frigidiſſimus. Hoc illi cum multis commune eſt.* And he gives this Reaſon, that in the Summer the Pores of the Earth (through which she warm Spirits break out) are open, which are ſhut in the Winter: from whence it comes to paſs, that thoſe Furnaces which warm the Water are forced to be hot; and for that Reaſon it is, that ſome Fountains are warmer by Night than by Day: All which is, I think, a moſt convincing Argument, that theſe, and other Kinds of Water, which might be named, are not derived from Rain.

Chap. III. Pag. 41. Line 1. —*have deliver'd it down, from the Foot of a large Hill or Mountain.* And here I cannot but again take Notice of what the ingenious Sir *Robert Cotton* has lately told me, of a ſtrange Spring which falls from a vaſt high Rock at *Dyſert* in *Flintſhire*; though it lies, as near as my ingenious Author could gueſs, five hundred Yards high; and that in a conſtant Stream, or rather Cataract of Water, tho' it is the higheſt Ground in all the Country: Another pregnant Reaſon why Springs have not their Original from Rain, but from the Sea. And this I think proper to precede the following Account I have from the Hiſtory of *Switzerland*.

Chap. III. Pag. 41. Line 3. *To all which may be added what I have read in an Account*, &c. The very Account which is here meant I have ſince met with, and is as follows: " It is believed, (ſays the ingenious " Author of it) that *Switzerland* is much " the higheſt Country of any Part of *Europe*; and two Reaſons are chiefly alledged to juſtify that Opinion: Firſt, the " Sharpneſs of the Air; and, Secondly, the " many Rivers that have their Source in it. " Which ſecond Reaſon is taken from an " Hypotheſis, That every River takes its " Source in higher Ground, than through " which it afterwards flows: And it cannot be deny'd, that many large Rivers " take their Riſe in theſe Mountains, ſince " there is found (inſtead of four that I have " mentioned in the Account to which this " is referred, and that at a ſmall Diſtance from " one another) the Sources of the *Adda*, " the *Ticino*, the *Lintz*, the *Aar*, the *Ruſs*, " the *Jun*, the *Rhone*, and the *Rhine*; beſides " which, one may reckon the *Danube*; for " tho' in Strictneſs it riſes without the Limits of *Switzerland*, yet it is but a few " Leagues diſtant from *Schaufhauſen*. The " *Ill* is another River which has its Riſe " near *Bazil*; and tho' the Source of the *Adige* be properly in the Country of *Tirol*, " yet it is upon the Confines of the *Griſons*. " Theſe (being eleven in Number) are the " moſt conſiderable Rivers in *Europe*, and " which all take their Riſe in this ſmall " Country of *Switzerland*, beſides which " there is ſcarce a Valley which has not a " River running thro' it. And as this extraordinary Number of Rivers, in proportion to what we find in other Countries of the ſame Extent, is brought as a " a convincing Argument of the natural " Height of the Country; ſo it will as naturally ſuggeſt the Impoſſibility there is of " Rain being the Author and Supplier of " them."

To proceed with this ingenious Author; " The Lakes which are to be found in that " Country are not to be omitted; of which " he remembers near thirty; ſome whereof " are ſo conſiderable, as to deſerve the " Name of Seas, as they are called in *German*; the Lakes of *Conſtance* and *Geneva* being near eighteen Leagues in Length, " and four in Breadth; and thoſe of *Neufchatel*, *Zurich*, and *Lucerne*, are not much " inferior to them in Length: And beſides " theſe Lakes in Plains and Valleys, there " is ſcarce a Mountain that has not one on " the Top of it, well ſtored with Fiſh, by " the Sale of which, they make the Inhabitants ſome Amends for the Loſs of the " Land they overflow. Upon the whole, " (ſays my Author) I never ſaw an Inland " Country that abounds ſo much with Water, as this does: Wherever one goes, " one finds an infinite Number of Springs, " the pureſt and ſweeteſt I ever taſted. And " there is ſcarce a Field or Meadow that " may not be laid under Water, whenever " the Husbandman thinks it neceſſary for " the Good of his Ground." Thus far Mr. *Stanyan*. To which I need but juſt remark, the great Difficulty there would be for the Maintainers of the Hypotheſes of Air, Vapours, or even Rain, for the Supply of ſuch a Number of great Rivers, Lakes, and Springs, and in ſo ſmall a Country, as that is. To this I may add what *Seneca*, and others, amongſt the ancient, as well as ſome modern Philoſophers, have aſſerted of the Depths which Rain-Water ſinks into the Earth in any Place, eſpecially on Hills, where it runs off with a much ſwifter Current, than from ſlow declining Lands. *Jam pluviæ maximæ non ultra decimum pedem in terram penetrant.* And an anonymous *French* Author, in a Treatiſe *De l'Origine des Fountains*, *Partie ſecunde*, *p.* 167. (who had made a curious Enquiry into this Matter) affirms, it does not ſink a Foot and a half; and all, or moſt of the Rains which fall in Plains, are conſumed in the Nouriſhment of Plants and Herbage.

Chap. III. Pag. 41. Line 30. *The laſt Thing to be examined in this Narrative of Springs*, &c. This is ſufficiently expreſs'd by Dr. *Plott*, *pag.* 70. in his Treatiſe of *Fountains*; to which he adds, *Nam ſiqua experimentis fides eſt habenda, vapores qui in auras exhalantur ad nubes, & qui in pluviis demittuntur, non tam è mari originem ducunt, quam à terræ* Madere; *atque hoc Pacto in Uliginoſis & Paluſtribus regionibus qualis eſt* Hibernia Nimbi *non ſunt frequentes, enim in aridis* Afriæ & Arabiæ *ſolutidinibus, vel nulli ſunt, vel rariſſimis ut mittam quanta cum difficultate; Aquæ ſalſuginoſæ, preparationem ſubeant, aut pluviis magis aſſiduas ex oriente*

&

& meridie provenire; id eſt, à continentis non oceano. Huc accedit imbres vehementiſſimis terræ meatus obtimare, adeo ut ſuſquipedem ſubſidere non poſſint, adeoque maximam partem diluviis abſtrahuntur: unde adhuc evidentius aquet, quam parum probabile ſit fontes tantæ magnitudinis (quantum memoratas diximus) à pluviis in tale conſervatorum decidentibus ſuppleri. All which I thought proper to ſet down in the Author's own Words, leaving the Deciſion of it to the curious Reader.

Chap. III. Pag. 44. Line 4. *The Exiſtence of ſubterraneous Fires, if any ſuch there are,* &c. That there are ſubterraneous Fires, or rather that there is a Kind of Reſpiration of warm Air through the whole Maſs of Earth, ſeems to me more and more probable; though whether this Heat reſides in the Center, and ſo diſperſes itſelf; or whether that Heat is innate, as proceeding from certain igneous Effluvia's, that are diſperſed here and there, is not certain: But from the Warmth there is in Cellars, as alſo that when you pump a few Strokes with any Engine, ſo that the cold Water goes off, after which, follows that which is warmer; 'tis certain, I ſay, that there is ſuch a Thing in Nature.

Theſe Fires break out, as *Rohault* in his *Phyſicks*, *Part* 3. *Cap.* 9. ſays, like thoſe which proceed from *Heclâ* in *Iſlandia*, or *Ætna* in *Sicily*, or *Veſuvius* in *Campania*; nor are they any other than thoſe which we blow up with our Bellows: But he confeſſes, that he is not able to explain their Nature. And yet Dr. *Woodward*, in his Eſſay, *Part* 3. *Conſect.* 13. ſays, "That "there are ſcarce any Countries that are "much annoy'd with Earthquakes, that have "not ſome of theſe fiery Vents; and thoſe "(ſays he) are conſtantly all in Flames, "Whenever any Earthquake happens, they "diſgorging that Fire, which whilſt underneath was the Cauſe of the Diſaſter (with "more to the ſame Purpoſe) and concludes; "In one Word, ſays he, ſo beneficial are "theſe to the Territory where they are, "that there do not want Inſtances of ſome "which have been reſcued, and wholly deliver'd from Earthquakes, by the breaking "forth of new Volcano's there; this conſtantly diſcharging that Matter, which "being till then barricadoed up, and impriſoned in the Bowels of the Earth, was "the Occaſion of very great and frequent "Calamities." Thus far Dr. *Woodward*. The Uſes that theſe Volcano's, or the innate Heat which labours in the Ground, is certainly to leſſen or take away the Weight of Air, which is mixed with the Earth, ſo that the Water may aſcend the freer, even as we ſee it in the *Æliop. le Terr. Sigma*, *&c.*

Chap. III. Pag. 49. Line 5. *Errata.* Inſtead of, not being explained, *read*, not being irregularly explained by the riſing of Water in a ſmaller Pipe.

Chap. III. Pag. 50. Line 3. *It is not much to the Purpoſe to examine, or confute the Opinion of thoſe who affirm, that the Depth of the Sea is no more in Perpendicular, than the Height of the Mountains above it.* The Profundity of the Sea, according to the Opinions of the moſt celebrated Geographers, is various; ſometimes $\frac{1}{80}$, $\frac{1}{40}$, $\frac{1}{20}$, $\frac{1}{10}$, $\frac{1}{4}$, $\frac{1}{2}$ of a Mile, *&c.* And in ſome Places where the Rope wont reach, they ſuppoſe it not leſs than a *German* Mile in Depth: But theſe Geographers don't deny but that in the Bottoms, thoſe Depths there may be Gulphs or ſubterraneous Meanders, thro' which the Water may paſs.

To uſe *Varenius*'s own Words, *In finibus maris profunditis multo minor eſt quam oceani, qui Alveus eſt minus profundus ſive minus excavatus, propter viciniam terræ ſicut eandem ob cauſam oceanus ad littora minus eſt profundus quam in remotis terræ locis quod accidit ob ſolam Alvei ejus figuram cavam.*

Chap. III. Pag. 51. Line 10. *To paſs by then all the curious Definitions of the Attraction here ſpoken of. Rohault* in *Part* 1. *cap.* 2. *Paragr.* 15. ſeems to be very ſilent as to Attraction, Sympathy, Antipathy, and the like, on the Account of their Obſcurity; and tells us, If you behold a Loadſtone, it is plain that there is in it an attractive Power, or, he would have ſaid, a very great Sympathy between it and Iron; but that he could neither explain the Nature nor the Properties of it.

But our learned *Newton*, who has been ſo great an Honour to his Country in diſcoveries

coveries Philosophical and Mechanical, puts the Question, *pag.* 322. of his *Opticks*, Whether, or no, the small Particles of Matter have not certain Virtues, Force, or Powers, which, by means of something thrown between them, they mutually join to one another, to the Introduction of most of the Phænomena's of Nature: Let me use his own Words, as it follows, what I have translated from him, *Satis enim natus est, corpora in se invicem agere per attractionem gravitatis*, &c.

Chap. III. Pag. 53. Line 1. *That the Sea and many large Rivers are higher in some Places, than the general Level of the Earth*, &c. The Truth of the Proposition, *Varenius* also testifies in *Cap.* 3. *Prop.* i, ii. from the famous geometrical Proposition of *Archimedes*, which is not found demonstrated in his Elements, but the Solution of which he himself has undertook, (viz.) *Let any Superficies be cut by Plains passing thro' any one Point of it, and let every Section of the Periphery of the Circle, having that Point for its Center, that Superficies must be spherical, whose Center shall be the Point before spoken of.* And to this Sphericity of the watery, as well as earthy Frame of the World, he prejoins, That it is the Nature of all Liquids, that] their Parts being of an equal Distance from the Center of the Earth, and lying and continuing one amongst another, the lesser Weight is expelled by the greater; for that every Part of a Liquid is pressed by that which is perpendicularly (in Respect to the Center of the Earth) above it; and that Liquid so descending is pressed by some other Body. And he concludes that first Proposition in these positive Words; *Oceani itaque superficies est spherica habens idem centrum, quod est terræ centrum: quod idem etiam ex sequentis propositionis confirmatione manifestum fiet.* And in Proposition the second he does not seem to endeavour to urge or prove that the Earth is lighter than the Sea; but that the Ocean is not of a greater Heighth than the Banks or Bounds of the Earth: And he concludes (contrary to what *Rohault* and others have set down on this Subject) *Atque ideo terra & aqua ejusdem fere sunt Altitudinis ubique exceptis montibus excelsis.*

The Middle of the Sea does indeed look as if it was much higher than the Land, as whoever approaches the same may discover; though this, I, and many other Authors doubt of: And the most I would endeavour to prove from the foregoing Argument is, that when the Waters, in the Scripture Phrase, are gathered together, (as they are in high Tides) then, if not always, the Middle thereof is as high as the approximate Shores, or Banks of Land-Hills, very high Hills excepted; which will be more fully explained by the following Note.

Chap. III. Pag. 55. Line 19. *But that the Sea in general (at least the middle Part of it) lies rounder than the Land*, &c. This is agreeable to what has been set down in the foregoing Article; and I would endeavour to infer no more from it in this, than that by the Congregation of the Waters, and their Concussion together, by the Gravitation of the Atmosphere, which presses upon them, and forces them towards the Shore, Water may, by the Laws of Hydrostaticks, (and other Powers just mentioned) rise with great Ease to the Tops of high Ground: For I do not aver (as some have) that the Sea is higher, but that it is as high as the general Part of the Land is; nor do aver, in this, that the Spring there mentioned rises on the Top, but rather the Middle, or more lower Part of the Hill.

Chap. III. Pag. 59. Line 22. *But if we consider the Flowings of the Tide*, &c. Here I observe, that if, according to the System of *Copernicus*, with whom *Kepler*, *Gallilæo*, and almost all of our modern Philosophers (tho' different from the exact Letter of the Bible) agree, that the Earth turns round upon its own Axis, and that the other Planets are fix'd and immoveable; amongst other Reasons, too many here to be named, for that the Course which the Sun must take is so many thousand Miles more than the Rotation of the Surface of the Earth, how great must that Shock be, which the Water receives by such a Rotation or Revolution; and though it does not (by the vast Number of Miles, of which the whole Circumference of the Earth is, together with its regular and uniform Movement) overturn Houses and Steeples, or put Men in Danger who are walking thereupon; yet Water is of so voluble a Nature, that it is not difficult

ficult to conceive how much it will force its Way up thro' the Crannies of the Earth, by ſuch a Movement, as when the Sea is, as it were, diametrically oppoſite, perpendicular, or ſloping to the Place, to which the Water is to paſs.

Chap. III. Pag. 59. Line 23. *How greatly muſt ſuch a Rotation contribute to the forcing the Water*, &c. This Obſervation is what I have not met with in any Account I have ever read of Springs, tho' it does not ſeem to be an improbable Conjecture; for, if the *Copernican* Syſtem holds good, which there is a great deal of Reaſon to believe it will, (*viz.*) *That the Earth makes a diurnal Rotation round its own Axis, and a periodical Revolution round*, how greatly muſt ſuch a Rotation contribute to the forcing of Springs out of the Chaſms and Fiſſures of the Earth? And the Imperceivableneſs of its Motion is a great Demonſtration of the Truth of this Suppoſition, than if it were quick and viſible. If you put Water into a Bowl, and ſwing the Bowl about with great Celerity, the Water wont indeed be much of it loſt; but if its Motion was to be leiſurely, to what Place is it that it will not find its Way? And why may we not ſuppoſe, that it is by this Means that Water iſſues out of ſuch Hills as it does, by or through thoſe Ducts or Channels, that Nature has formed for that Purpoſe.

Whoever will be ſatisfy'd of the Probability of the *Copernican* Syſtem, before that of the *Ptolomean*, may have Recourſe to the the Works of *Rheticus*, *Kepler*, *Rothman*, *Landsberge*, *Gaſſendus*, *Gallilæo*, and others; but more particularly to the Reverend and Learned Mr. *Derham*, in his Preliminary Diſcourſe to his *Aſtro-Theology*, *pag.* 7.

Chap. III. Pag. 61. Line 32. *It will not be improper to take a ſhort Survey of what Authors have ſaid of that Deluge.* Of the Eruption of Springs out of Hills, beſides what the Scriptures have ſaid concerning the Formation of the World, and of this Deluge, *Ovid*, *Cap.* 1. *Pag.* 2. *Line* 38. thus has it.

Juſſit & ambitæ circundare littora terræ,
Addidit & fontes, immenſaque ſtagna lacuſq;
Flumina obliquis cinxit declivia ripis;
Quæ diverſa locis partim ſorbentur ab ipſa;
In mare perveniunt partim, campoque recepta
Liberiores aquæ, pro ripis littora pulſant.

But when he comes to give an Account of that fatal Eruption of Water, with which the World was drowned, the Poet is ſo wonderful plain in his Diſtinction between the Rain from above, and the Deeps below, that one would think he had conſulted Holy Writ itſelf.

Nec Cœlo contento ſuo Jovis Ira.

And a little after, ſpeaking of the Deeps,

——— *Vires effundite veſtris:*
Sic opus eſt. Aperite Domus: ac mole remota.
Fluminibus veſtris totas immittite habenas.
Juſſerat, hi redeunt, ac fontibus ora relaxant,
Et defrœnato volvuntur in æquora curſu.
Ipſe tridente ſuo terram percuſſit: at illa
Intremuit, motuque ſinus patefecit aquarum
Exſpatiata ruunt per apertos flumina campos.
Ovid. Metam. lib. 1. cap. 1. v. 277. &c.

Virgil, tho' he has wrote nothing direct (at leaſt that I have met with) concerning the Original and Riſe of Springs, yet he has left ſeveral ſhort Hints of his Opinion on this Head, where he always, however ſoft his Subject was, talks of nothing but its precipitate Eruption.

Thus Georg. lib. 1. v. 203.

Atq; illum in præceps prono rapit Alveus amni.

And Georg. lib. 3. v. 428.

Qui dum amnis ulli rumpuntur fontibus & dum
Vere Madem udo terræ.

And Æneid. lib. 1. v. 105.

— *inſequitur cumulo præreptus aquæ mons,*
Hic ſummo in fluctu pendent: his unda dehiſcens
Terras inter fluctus aperit.

Chap. IV. Pag. 65. Line 20. *Natural Hiſtories produce an infinite Number of ſuch Springs*, &c. I might have produced a much larger Number of ſuch Springs, in Confirmation of this Chapter: Such are the Fountains near the Lake *Aſcanius*, which, as

Agricola

Agricola ſays, *Lib.* 3. of his Book *De Natura Rerum quæ effluunt ex terra*, are dry in the Winter, but are filled up to the Brims in the Summer. The ſame he relates of a Fountain *ad Calidas Lucenſes*, to uſe his own Words, *qui per totam æſtatem a* Maio *ad* Septembrem *uſque uberrime ſecturo, deinde ſic ſubducere. Geo. Weanerus* (as Dr. *Plott* has it) ſays the ſame Thing of another in *Helvetia — qui ſemper* Auguſto *menſe areſcit; nec ante* Junium *inſequentem rurſus emergit.*

Chap. V. Pag. 77. Line 12. *In the following Places Springs are certain and good.* The Reverend and learned Mr. *Derham*, who, for the Juſtneſs of his Obſervations, is ſo much admired, ſays, in his Notes *Book* 3. *Cap.* 2. *Pag.* 65. of his *Phyſico-Theology*, That it is not only agreeable to Reaſon, but as he was told by Perſons converſant in digging of Wells throughout the County of *Eſſex*, where he lived, that the ſureſt Beds in which they found their Water were Gravel, and a courſe-colour'd dark Sand, which Beds ſeldom fail'd to yield Plenty of ſweet Water: But for Clay, they never find Water therein, if it be a ſtiff ſtrong Clay; but if it be lax and ſandy, ſometimes Springs are found in it; yet ſo weak, that they will ſcarcely ſerve the Uſes of the ſmalleſt Family. And ſometimes they meet with thoſe Beds lying next under a looſe black Mold, (which by their Deſcription he judged to be a Sort of Ouze, or to have the Reſemblance of an ancient Ruſhy Ground,) and in that Caſe the Water is always naught, and ſtinks. And laſtly, another Sort of Bed they find in *Eſſex*, in the clayey Lands, particularly in that Part called the *Rodings*, which yields Plenty of ſweet Water, (and that is,) a Bed of white Earth, as tho' made of Chalk and white Sand. This they find after they had dug thro' forty (or more) Feet of Clay; and it is ſo tender and moiſt, that it will not lie on the Spade, but they are forced to throw it up into their Bucket with their Hands, or with Bowls: But when it comes up to the Air, it ſoon becomes a hard white Stone. And thus much, ſays my Reverend Author, for the Variety of Beds wherein the Waters are found. And that it is in theſe Beds only, or chiefly, the Springs run, is farther manifeſt from the forcible Eruption of the Waters out of thoſe watery Beds: And this Eruption, ſays he, ſhews, that the Water comes from ſome Eminence, or other, lying at a Diſtance, and being cloſely pent up in the watery Stratum, by the Strata of Clay, the Waters with Force mount up.

Chap. V. Pag. 81. Line 27. *When you have pitched upon a Place that is proper to bore for Water*, &c. Thoſe who have wrote of the Formation of the Earth, ſay (*Vid. Steno's Prodrom.* and Dr. *Woodward's Eſſay, Part* 2.) that when the terraqueous Globe was in a chaotick State, and the earthy Particles ſubſided, then theſe ſeveral Beds were in all probability repoſited in the Earth, in that commodious Order in which they are now found; and that is as aſſerted according to the Laws of Gravity. But Dr. *Leigh*, in his *Natural Hiſtory of Lancaſhire*, ſpeaking of the Coal-Pits, denies the Strata to lie according to the Laws of Gravitation. In anſwer to which, Mr. *Derham*, being ſuſpicious that no real Experiment had ever been made of it, try'd it himſelf, and found, that the Strata in his Yard were gradually ſpecifically heavier and heavier the lower and lower they went; and the upper, which was Clay, was conſiderably ſpecifically lighter than the lower Stratum, which was a looſe Sand and then a Gravel; in which Strata the Springs ran which ſupply'd his Well. And here it may again be obſerv'd, that Springs run rather under than above Clay, which they would not do, did they owe their Original to Rain.

Chap. V. Pag. 82. Line 4. *When they dug down ſuch a Pile as I have been before deſcribing*, &c. To this I add what Monſ. *Blondell* related to the *Pariſian* Academy, concerning the Devices which the Inhabitants of the *Lower Auſtria* were wont to uſe when they wanted Water: They dug down to the Depth of 20 or 25 Foot, till they came to an Argille or clammy Earth, which they bored through ſo deep, till the Waters broke forcibly out; which Water, it is probable, comes (I add) from Springs which riſe up in and from the neighbouring Mountains in ſubterraneous Channels. And *Caſſinus* obſerves, that in many Places of the Territories of *Modena* and *Bologna* in *Italy*, they make themſelves Wells by the ſame Artifice, &c. By this Means alſo the ſame Seignieur *Caſſini* made a Fountain at the Caſtle

of

of *Urbin*, that caſt the Water up five Foot above the Level of the Ground; as whoever ſees Mr. *Ray*'s Diſcourſe, *p.* 40. may be better informed And this is a Demonſtration, that Water riſes firſt of all into the Tops of high Hills, and after that deſcends into low Grounds; and not from Rains, which run off ſo precipitately, that they ſcarce enter a Foot into the Ground.

Chap. VII. Pag. 97. Line 18. *This new Invention, or, at leaſt, this great Improvement of an old one*, &c. Since the Printing of the foregoing Sheets, I have had an Opportunity of being farther and better informed of the Nature, Size, and Prices of the earthen Pipes I have there recommended.

In the firſt Place, I obſerve, that the Undertakers have not as yet made any above three or four Inches Diameter, being a little cautious how they adventure too far at firſt, though they have ſome Hopes to make them larger: Neither are they fond of uſing them on the Outſides of Houſes, becauſe they are more liable to be broken there than any where; but they are excellently uſeful in carrying off Water which is to go down in the Walls or Inſide of a Houſe, taking up ſo ſmall a Column of the Wall, that it does not weaken it.

In the ſecond Place, I obſerve, that the Cement with which they join them is not ſuch as *Vitruvius* tells us the *Romans* uſed; but is much ſtronger, and ſomething of the Nature of that with which Statuaries join on particular Limbs and Parts of broken Statues, *&c.* And this Cement is not liable to an Objection, which I have heard has been brought againſt thoſe Pipes, in relation to a Weed, which, with its Fibres, is apt to choak up the Pipe; but this Cement is neverthelеſs diſſolvable by Heat, whenever you have a Mind to repair a broken Pipe: And it is farther obſervable, that this Cement is ſo ſtrong, that any other Part of the Pipe will ſooner break than the Joint.

In the third Place, I obſerve, that as there are ſome, though not very many Pipes in every Kiln, which are a little faulty, and ſubject to a few Flaws or Cracks, that theſe Pipes are nevertheleſs uſeful, wherever you have great Plenty of Water to ſupply them; as is the Caſe where you lay Pipes to ſupply Gardens, from the *Thames*, or other large and plentiful Rivers; for there, tho' there is ſome Waſte, yet the great Supply is ſuch, that it will not be minded. And theſe Kind of damag'd Pipes may be alſo uſed, wherever you are to convey Water thro' Drains from the Eves or Roof of a Houſe, Stable, *&c.* eſpecially if it runs through a Gravel; for there the Sinking-away of Water is of no great Moment.

Having very lately receiv'd the following farther Account of theſe Clay Pipes, I have been here recommending, I beg Leave to inſert it for the Benefit of my Readers, and that there may be nothing wanting that may recommend ſo uſeful an Invention.

The Account runs thus:

MR. *William Edwards* of the Town of *Monmouth*, Patentee for the ſole Making and Vending of his new-invented Water-Pipes, made of common Clay, by a particular Method, and in a Manner never heretofore practiſed by any Perſon but himſelf.

And by whoſe Directions they have been ſo placed and diſpoſed in Buildings, to carry the Water from the Roof and Gutters of Houſes, and diſcharge the Water on the Surface of the Earth, and into the common Sewer.

And likewiſe he has, by his Servants, laid great Quantities of theſe Pipes underground, for Aquæducts, that now do convey the Water for Eighteen Hundred Yards in Length, diſcharging the ſame Quantity taken in, without the leaſt Waſte.

They are allowed by Men of the beſt Quality, and Gentlemen of the beſt Taſte, in this Way, to exceed Lead or Wood Pipes, both of which are periſhable; whereas theſe will endure Ages to come, or, what may be ſaid, to Perpetuity.

Great Expence and Trouble is beſtowed in preparing the Clay; as Pitting, Waſhing, Ridling, Grinding it in a Mill, Treading it with Mens Feet, and Working it with their Hands into Meſſes, and then it is form-

ed into Pipes upon a Potter's Wheel to any reaſonable Subſtance: When they are dried to a Temper, they are put upon a Mandrel, or Plug of Wood, and turned to great Exactneſs upon a Turner's Lathe, one End being engrafted into the other, groove-wiſe, that receives the melted Cement, or Sodder ſo artfully into the Joints, which becomes by it more ſtrong than any other Part of the Pipe, altho' very remarkable for their Hardneſs, bearing a Fire in their Burning, of the greateſt Violence, for five or ſix Days and Nights ſucceſſively, inſomuch that they become as impenetrable and hard as Flint; and, by the Uſe of a Steel, you may ſtrike Sparks of Fire from Pieces of them, that will light Tinder, as from Flint.

Conſidering the great Labour and Expence to bring them about, with the great Quantities that break, by the Violence and any extream Change of Weather, and other Incidents in carrying them to and from the Kiln, as well as their Breakage in it, they cannot be ſold for leſs than the Prices following; two Inch Bore in the Diameter being the leaſt Size made:

	s.	*d.*
Two Inch Bore (*per Yard*)	02	00
Three Inch Bore	03	00
Four Inch Bore	04	00

And ſo on 5, 6, 7, ſo many Shillings.

But a ſecond Sort may be made, for Works that require leſs Strength, and of Clay unprepar'd, and not digeſted as afore-mention'd, for and after the Rate of 9*d. per Yard* every Inch in the Diameter; that is to ſay:

	s.	*d.*
Two Inch Bore (*per Yard*)	01	06
Three Inch Bore	02	03
Four Inch Bore	03	00

And ſo on in Proportion.

All Pipes are try'd upon Delivery; and if any prove crack'd or defective, they are laid aſide, to be uſed in Drains, or in any weak Current of Water, and are ſold for half Price as others are.

And to make all theſe Pipes more effectually good and ſerviceable, in all Caſes and Works whatſoever, Mr. *Edwards* has very well conſider'd the Power of Air, as well as Water, and their Operations as confin'd within theſe Pipes, and has lately found out, contrived, and made Braſs Valves, or Clacks, placed within his ſaid Pipes, at a proper Diſtance, which diſcharge the Air, and, as the Water prevails, throw up the Clack that confines the Water from iſſuing out, and prevents all Strugglings in the two Pipes, which takes off two Thirds of that Power, (which is generally called Friction, or rather the Interpoſition of Air,) and facilitates the Delivery of the Quantities of Water they ought: By which Means he now makes Uſe of theſe Pipes to convey Water from Engines of great Force to Reſervoirs ſix hundred Yards in Length, and ſixty Foot high; and, as far as I am capable of judging, Mr. *Edwards* has brought them to ſo great Perfection, that he is able to anſwer all Objections that can be raiſed againſt him: And theſe Pipes will, I doubt not, be of great Uſe in many Things not yet thought of, as they are in Cities for Upſtair Bog-Houſes, &c.

He has an Art in laying theſe Pipes in their Work, that if a Sediment of any Sort works into them, he lays in four, five, or ſix Foot of waſte Pipe for a Lodgement for it, which is inſtantly diſcharged.

Any Work that's practicable to be done, for 6*d. per Yard*, two Inch Bore, and all as proportionable in larger Sizes, he will inſure their Performance.

From the foregoing Calculations of the Prices or Expences of the different Kinds of Piping, I have drawn the Table following, omitting Iron, which are ſeldom or never caſt in ſmall Molds; beſides rejecting Alder, Fir, and all thoſe other Kinds of Piping, I draw the Parallel only between the three Kinds ſo much in Diſpute, which are Lead, Wood, or Clay. And, as to the laſt, I divide them into two Kinds, (*viz.*) thoſe which are the ſtrongeſt and beſt burnt, and thoſe which are a little crack'd in the Burning; to which I ſhall add a third Sort, which were made by my Friend Mr. *Mutchell*, before

before the Patentee and he had come to any Terms of Agreement, and which will undoubtedly ſerve in all ordinary leiſurely Falls, or at the Extremity of a Force Work.

To this I ſubjoin, that the Price of the leaden or wooden Pipes are reckon'd naked, and at the prime Coſt, without Solder in one or Iron Bands in the other, the Coſt of which is uncertain; but ſtill makes the Difference between them the greater. To this I may ſtill add, that the Prices of Lead are ſometimes much greater than I have ſet down; and tho' it may be ſaid in Juſtification of Lead-Pipes, that they will ſell at laſt, if any Gentleman has a Mind to it; yet 'tis to be ſuppoſed, in Anſwer to it, that there are few that lay Pipes with any View but to Perpetuity. How long Lead-Pipes will laſt, without being eat, or worn out by the Earth they lie in, I need not expatiate on; nor need I ſet down how much Elm-Pipe decays in a little Time, nor how ſubject they are to burſt.

	Lead		*Wood*		*Beſt Clay*		*2d Beſt Clay*		*Crack'd Clay*	
Inch Bore	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
2	6	0	1	3	2	0	1	6	1	0
3	9	0	2	0	3	0	2	3	1	3
4	20*s.* and upwards		2	6	4	0	3	0	1	6

Upon a View of the above Table, it appears, that the Expence of Clay Pipe does not riſe, in Proportion to their Diameter, as Lead and Wood, on the Material, unavoidably does; for a Pipe of Lead of 2 Inch Bore is three Times the Charge as that of the beſt Clay) whereas a Pipe of 4 Inch Bore in Lead is above five Times the Expence of it in Clay. As to the Expence of the Cement which joins the Pipes together, that is of little Value, and the digging and laying of every Kind is always the ſame: So that I leave every Gentleman from this View to determine with himſelf, which of the Pipes are moſt eligible, ſuppoſing that the Clay will ſuſtain any Perpendicular Weight, or even the ſtrongeſt Stroke of an Engine, which I dare anſwer they will, eſpecially if you lay 38 or 40 Yards of Iron Pipe next to the ſaid Engine? which is all I have to add in this Affair.

Chap. VI. Line 1. Lib. 6. Pag. 96. *Here follows a Table of the Earth's Curvature*, &c. This Note ſhould have been put in another Place, but that it was in a Hurry overlooked: However, that I may do the utmoſt Juſtice I can to the Memory of ſo great a Man, I ſhall recite his Opinion on this ſo Mathematical and uſeful a Calculation, as it relates to the Curvature of the Earth, and therein the Conveyance of Water from one Place to another.

This ingenious Gentleman, *Pag.* 58. of his *Mathematical Compendium*, that in carrying a Stream or River, ſuch as the *New River* from a little above *Ware* to *London*, or elſewhere, you muſt allow a Foot, or a Foot and two Inches, for a Mile in Deſcent, or more, if your Fall requires it; and this becauſe of the Tangent from the Surface of the Globe of the Earth in every Mile; and tho' in a Mile it will be found to be but ſix Inches, yet it is better to hold to the ſurer Side; tho' later Experience ſhews, that this great Man was miſtaken, for that Water will deſcend very well in an open Sewer at about four Inches, or four Inches and a half in a Mile's Fall.

But for Common Sewers, or Paſſages to carry off Water and Dirt in Streets and Towns, for every ten Foot, you ought to allow two or three Inches Fall, or more, if you can, which in every hundred Foot will be one Foot eight Inches Fall. If you allow two Inches, or two Foot ſix Inches, you allow three Inches; and the more the Fall will allow, the better it is.

This Note I alſo inſert, for that I have by Miſtake miſrepreſented what this ingenious Author ſays, as to the Deſcent proper for Water, which Miſtakes are to be found *pag.* 103, 104.

Chap. V. Pag. 83. Line 26. *When you dig for a Well, great care ought to be taken of the Steneing* (not Stewing it, as it is, by Miſtake, in the printed Sheet) *the Sides, to*

keep

keep it from tumbling in, but to take care that the Effluvia's of the Water, &c. This is the Direction of the learned *Vitruvius*, as *Varenius* tells us from *Lib.* viii. *Cap.* 7. and not *Lib.* x *Cap.* 6. is in the Deſcription before-going, which is ſo particularly ſet down by thoſe Authors, that I ſhall finiſh theſe *Annotations* with a full Account of it: *In puteorum autem foſſionibus non eſt contemnenda ratio, ſed acuminibus ſolertiaque magna naturales rerum rationes conſiderandæ; quod habet multa variaque terra in ſe genera. Eſt enim, uti reliquæ res, ex quatuor principiis compoſita; & primum eſt ipſa terrena, habetque ex humore aquæ fontes. Item calores, unde etiam ſulphur, alumen, bitumen naſcitur, aeriſque ſpiritus immanes; qui cum graves, per intervenia fiſtuloſa terræ, perveniunt ad foſſionem puteorum, & ibi homines offendunt fodientes, naturali vapore obturant in eorum naribus ſpiritus animales: ita qui non celerius inde effugiunt, ibi interimuntur. Hoc autem quibus rationibus caveatur, ſic erit faciendum. Lucerna accenſa demittatur, quæ ſi permanſerit ardens, ſine periculo deſcendetur. Sin autem eripietur lumen vi vaporis, tunc ſecundum puteum dextra ac ſiniſtra defodientur æſtuaria, ita (quemadmodum per nares) ſpiritus ex æſtuariis diſſipabuntur. Cum hæc ſic explicata fuerint, & ad aquam erit perventum, tunc puteus ita ſepiatur ſtructura, ne obturentur venæ. Sin autem loca dura erunt, aut in imum venæ penitus non fuerint, tunc ſigninis operibus ex tectis, aut a ſuperioribus locis excipiendæ ſunt copiæ. In ſigninis autem operibus hæc ſunt facienda, uti arena primum puriſſima aſperimaque paretur, cæmentum de ſilice frangatur, ne gravius quam librarium, calx quam vehementiſſima mortario miſceatur, ita ut quinque partes arenæ ad duas calcis reſpondeant: mortario cæmentum addatur, ex eo parietes in foſſa ad libramentum altitudinis futuræ depreſſa, calcentur vectibus ligneis ferratis. Parietibus calcatis, in medio quod erit terrenum, exinaniatur ad libramentum imum parietum, & exæquato ſolo ex eodem mortario calcetur pavimentum ad craſſitudinem, quæ conſtituta fuerit. Ea autem loca ſi duplicia aut triplicia facta fuerint, uti percolationibus aquæ tranſmutari poſſint, multo ſalubriorem ejus uſum efficient. Limus enim cum habuerit quo ſubſidat, limpidior aqua fiet, & ſine odoribus conſervabit ſaporem: ſi non, ſalem addi neceſſe erit, & extenuari.*

AN INTRODUCTION TO A General SYSTEM OF HYDROSTATICKS and HYDRAULICKS.

BOOK II.

CHAP. II.

Of Hydroſtaticks, its Etymology, Definitions, &c.

WITHOUT Doubt the Etymology or Derivation of Hydroſtaticks, though it is (being a Compound) a Word rarely to be found in any of our Gloſſaries, (at leaſt in any of thoſe that have fallen into my Hands) is from ΥΔΩΡ or perhaps rather from ὑδρὸς *Aqua*, Water, or of or belonging thereto, and ςατικὴ *Statice*, which ſignifies a weighing or ballancing, which being join'd together ſignify the Equipondium, weighing or ballancing of Water and other Liquids; and in this Senſe *Marriotte* and other Writers in Hydroſtaticks uſe it, when they diſcourſe of the Equilibrium of Water, and other Liquids and Fluids, by their Gravity, Elaſticity, Impulſe, and the like.

OZANAM defines Hydroſtaticks to be that Part of Mechanicks, which conſiders the Weight of Liquids, and eſpecially

 of

of Water, or ſolid Bodies immers'd into or laid upon Liquids, by comparing them with each other, and that though Liquids are ponderous, nevertheleſs they have not of themſelves a Center of Gravity, becauſe their Parts are not ſo link'd together as to ſuſtain one another in Equilibrio about one certain Point, unleſs they are ſhut up in a Veſſel, and then there may be obſerv'd a great deal of Conformity occurring in Staticks, and Hydroſtaticks which will be occaſionally explain'd.

For as by Staticks, it is known, that the Weight of Bodies encreaſe according to their Diſtance from the Perpendicular, juſt ſo on the contrary it is known by Experience; in Hydroſtaticks that the Weight encreaſes its Gravity, as it comes nearer to a Perpendicular; but of this more in its proper Place, and to go on.

Altho' the Word Hydroſtaticks ſeems in its literal Conſtruction to belong to Water only, yet it is now us'd more generally, and is apply'd to all Sorts of Fluids, as Air, Flame, &c. to which may be added of Liquids, Oyl, Mercury, Wine, Ale, Beer; becauſe all theſe other Bodies naturally fall within the Compaſs of Hydroſtaticks, though they have not exactly the ſame Properties as Water has; for Air, Flame, and I may add Sand, are Fluids (as *Marriotte* Part 1. Diſcourſe 1. well defines) Oyl, Mercury, and other Liquors are both fluid and liquid; for every Liquid is a Fluid, but every Fluid is not a Liquid.

By a Liquid is meant ſuch a Fluid as being in a more ſufficient Quantity will flow and extend itſelf under the Air, till its upper Surface be level, and becauſe Air and Flame want that Property, they are not call'd Liquids but Fluids; ſo alſo Hardneſs and Firmneſs are oppos'd to Fluidity, becauſe a hard Body, ſuch as Iron and Stone, is paſs'd through with much greater Difficulty, than Liquids and Fluids are, and when it is paſs'd through, its Parts do not ſo eaſily unite and join together again; on the contrary Fluids, ſuch as Air, Water, &c. immediately reunite, and in this it is that Fluidity conſiſts.

So alſo it is that fine Sand may be call'd a Fluid, but not a Liquid, becauſe it does not run or flow upon an inclin'd Plain, and when a Veſſel is fill'd with it, the upper Parts do not of themſelves run to a Level ſo eaſily as Water does.

I Shall in ſome of the following Chapters define and explain the wonderful Properties of Air, and its Uſes in Hydroſtatick and Hydraulick Motion; but as Water is the chief Thing to be conſider'd in this Chapter, it ſeems requiſite I ſhould make the cleareſt Definition of it I can, in what Manner it is compar'd with

with other Fluids, eſpecially Air, and conſider'd of in Relation to itſelf.

Now by Water is not meant that Part of the Globe ſo call'd, nor do we build or even conſider it according to that of *Archimedes*, who lays it down as a Rule certain *that the whole Body of Water is ſpherical* (even when it is not moved) *and that its Superfices has for its Center that of the whole Earth*; but in Relation to Air and Water it is neceſſary to have a Regard as well to certain Things whereof they are capable, as to thoſe wherein they cannot ſuffer any Accident.

For Water, though it may be extended by the Intermixture of Air, or attenuated or converted into Air by the Means of Heat which reſolves it, yet neverthleſs it can't be preſs'd; that is to ſay, that a certain Quantity of Water cannot be forc'd by Compreſſion, ſo as to be contain'd in leſs Space then its natural State: Whereas Air, on the contrary, may be reſtrain'd and put up, when it is preſs'd or rarified, or mov'd beyond the other Accidents of which it is capable; all which will be demonſtrated by Propoſitions deduc'd from Experience itſelf in the Courſe of the enſuing Treatiſe.

And to proceed in Relation to Water abſtracted from thoſe Properties, there are ſeveral others which are produc'd in the Hydroſtatick Way of Reaſoning, ſome properly and others improperly.

As firſt that * Water is call'd moiſt or humid tho' improperly, notwithſtanding *Archimedes* himſelf in his two excellent Books *de Inſidentibus Humido*, Part 24. as we have it from the learned *Barrow*, uſes it in that Senſe, becauſe ſay they, it is only that which is moiſtned by Water, that can properly be call'd humid, and in this Senſe it is that Air is humid, when fill'd with aqueous Vapours; Dryneſs is contrary to Humidity, and a Cloth which is ſaid to be humid, when it is wet, is ſaid to be dry, when the Water whereby it was wet, is evaporated.

2*ly*. Water is hard and liquid ſucceſſively, its natural State being Ice, that is, when no external Cauſe acts upon it, it remains firm by the Froſt or any other artificial Cauſe, and not liquid, and again upon a moderate Degree of Heat it becomes liquid and flowing.

3*ly*. In Water, I may add Wine &c. there is an aerial Matter that is intermixt with it, as may be perceiv'd when you ſet a

* Whoever will be more fully ſatisfied of the Nature of liquid and hard Bodies in general, and of the ſeveral Properties of Water in particular, may have Recourſe to *Rohault*'s Phyſicks, with the Notes on it by our learned Dr. *Clarke* Rector of St. *James*'s, Part 1. Chap. 22. Pag. 109. &c. Where it is very curiouſly handled and explain'd by thoſe two great Men.

Veſſel of Water upon the Fire; for then ſeveral Bubbles of Air form themſelves at the Bottom of the Veſſel, and afterwards riſe up to the Top of the Water; ſuch kind of Bubbles alſo are form'd in Water when it freezes, which finding no Paſſages through the Ice, do in its endeavour to extend itſelf, break the ſame.

4*ly*. That all Particles of Air have a centrifugal Force which repel each other from their reſpective Centers; which is the Reaſon why Air in Water takes up more Room when in Bubbles, than when it is as it were inviſibly diſpers'd and diſſolv'd in Water; for when thoſe ſeveral Particles of Air are got together in the Form of a Bubble, then their centrifugal Force exert themſelves ſo, as to make them recede farther from each other, than they would do were there Particles of Water between them, which bring the Particles of Air nearer together, in their repelling Force, than they would otherwiſe allow.

And 5*ly*. from the following Experiments it may be known that Air will inſinuate itſelf into Water or any other Liquid; for if you boil Water for three or four Hours, and when it is cold again fill a ſmall glaſs Vial full of that Water, then putting your Finger on the Vial, invert in it a Glaſs of Water in ſuch a Manner that there be a Bubble of Air at the Top of the Water about as big as a hazle Nut; then you will find that in twenty four Hours the Bubble will diſappear, and by trying the ſame Proceſs over and over again you will find the ſame Effects till the Water will ſuck in no more.

This is certainly demonſtrable by bottled Ale, for if you fill the Bottle but half Way up to its Neck and cork it well, the Air that remains in that Space will by Degrees inſinuate itſelf into the Liquor, and is in a great Meaſure that Spirit which preſerves and gives it that Briskneſs, with which after ſome Continuance it abounds, which with ſeveral Obſervations on Spirits of Wine *&c.* are ſufficient Demonſtrations that there are great Quantities of imperceptible Air, in Water and other Liquids, which is the Cauſe of a kind of Elaſticity in it, becauſe abſtracted from it there is no ſenſible Elaſticity in Water itſelf, any other than that it makes an Equilibrium with other Bodies by its own Weight, or by the Impulſe which it thus receives from Air.

There is alſo a ſixth Property in Water, which, how improperly ſoever it be, has taken Place in the *Carteſian* Philoſophy, and that is that Viſcuoſity which is by them ſuppos'd to be in it, and that every Particle of Water being in a conſtant Motion have a Kind of Figure proper to hook and unite themſelves to thoſe of the

2 ſame

ſame Kind, and that they faſten to each other aſſoon as by that Motion they come to touch, which is the Occaſion of that Friction that is againſt the Sides of Pipes, *&c.*

But this Viſcuoſity may be rather (as Dr. *Deſaguliers* in his Notes on *Marriotte* has it) call'd the Attraction of Cohæſion, by which the Parts of Bodies cohere ſtrongly in Contact, but act but very little one upon another at a ſenſible Diſtance, as that of a Drop ſqueez'd from an Orange demonſtrates.; for if Cohæſion were owing to the hooking of Particles together, there muſt be ſecond Hooks to hold the firſt, and third Hooks to hold the ſecond, and ſo on *ad infinitum*, which is a very unphiloſophical Suppoſition; and that this Cohæſion relates to Friction, or which is indeed a Term more proper for it, will be farther demonſtrated in its proper Place.

From theſe Preliminaries then concerning the Etymology of Hydroſtaticks, the Definition of Liquids and Fluids, and the Properties of Water, *&c.* let us, to ſum up all, have Recourſe to the Method Dr. *Deſaguliers* has defin'd the Principles of Hydroſtaticks by, in his excellent Lectures on Experimental Philoſophy, in the following Manner.

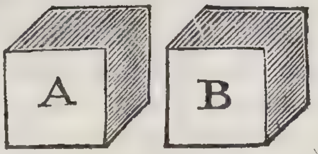
1ſt. " A Fluid is a Body, whoſe Parts yield to any Force im-
" preſs'd, and by yielding are eaſily put in Motion.

2dly. " A Solid is a Body whoſe Parts are ſo connected, as not
" to be divided without a determinate Force; but by Solidity he
" does not mean that Property of Bodies whereby they reſiſt Pene-
" tration, but the Cohærence of the Parts, by which they endea-
" vour not to be ſeparated; and thus as before according to *Ozanam*,
" a Fluid is a Body which is eaſily paſſed through, and whoſe ſepa-
" rated Parts join again immediately; as Air, Flame, Water, Mer-
" cury, and other Liquids do: A Liquid, which is a Fluid alſo,
" continually ſpreads itſelf below the Air, till its upper Surface is
" level, or in a Horizontal Poſition, *ut antea.*

3dly. " Gravity is that Force, which puſhes Bodies downwards.

4thly. " One Body is ſaid to be intenſely or ſpecifically heavier
" than another, when it has more Weight, and the ſame Bulk, or
" as much Weight and a leſs Bulk.

" LET A, be an Inch Square of Wood, and B, an Inch of Lead
" if B weighs 4 Ounces, and A but
" one, B will have four Times the
" ſpecifick Gravity of A.



" OR, let A be an Ounce of Wood,
" and B an Ounce of Lead, if A be
" four Times greater than B, then B
" will have four Times the ſpecifick
" Gravity of A; for there is a reci-
" procal Proportion between the Bulk,
" and the ſpecifick Gravity of Æqui-
" ponderous Bodies.

See the Squares.

THE Properties of Fluids in Reſpect to their Gravitation, &c. have been handled in a very accurate Manner by the learned *Wallis*, *Boyle* and others, in near 20 Propoſitions; all which may, I think, be reduc'd into two, and thoſe are concerning thoſe Bodies which preſs upon the upper, and thoſe that preſs upon any Parallel Surface within the Fluid.

THE primary Property of heavy Fluids are theſe, (to uſe the Words of a learned Divine on this Head) that if a heavy Fluid, as A, B, C, D, *(Fig.* 1. of the following Plate) be either not preſs'd at all, or equally preſs'd from above, its upper Surface A, B, will lie Horizontal or Level. And if the ſaid Level be diſturb'd, it will by its own Gravity return to the ſame Level of its upper Surface; for the lower Particles of the Fluid will not, by Reaſon of their Gravity, aſcend upwards of themſelves to raiſe any Part of the ſaid Surface above the other; (for as Dr. *Deſaguliers* demonſtrates Prop. 1. of his Hydroſtaticks, the ſuperiour Parts do preſs upon the inferiour by their Gravity;) nor can thoſe upper Particles deſcend, ſince there is no Room for them in the lower Part of the Veſſel, it being taken up by thoſe other Particles of equal Weight with themſelves: And therefore if there be no Preſſure at all from above, or an equal Preſſure, then there is nothing to diſturb or alter the Level of the upper Surface; but if it be diſturb'd, the Fluid will return to its Level, becauſe the higher Part H, I, *(Fig.* 1. *Tabulâ ſeq.)* being heavier, will partly depreſs the Particles under it, and will partly run down into the lower Part, and that ſo long as any one Part of the Surface is higher than the other.

AND on this Principle (as the learned Dr. has it) are founded all Water-works and Fountains; that according to the Height of

of their Reſervatories, ſo high will the Water riſe (*viz.*) if the Reſervatory be twenty Foot, the ſpouted Water will riſe twenty Foot, allowing for the Reſiſtance of the Air.

To demonſtrate this Principle farther. If the Fluid (*Fig.* 2. of the following Plate) be from above unequally preſs'd, it is obvious, that the Part thereof A, E, which is moſt preſs'd, will deſcend, the Particles ſo preſs'd thruſting out of their Places the other Particles, that are either not preſs'd at all, or leſs preſs'd; which therefore will aſcend to H, I, in Proportion to the Deſcent I, G, of the Particles preſs'd A, E, namely, as the Part preſs'd A, E, is equal to or not leſs preſs'd, E, B, ſo the Aſcent E, H, or B, I, will be equal to the Deſcent A, F, or F, G.

WHAT has been ſaid of the upper Surface A, B, holds good of any other parallel Surface within the Fluid, as E, F, (*Fig.* 3.) namely, if it be equally preſs'd by the upper Part of the Fluid, and withal by any thing elſe ſwimming, either at the Top or within the Fluid, it will retain its Horizontal Situation or Level; but if it be any where preſs'd more than in other Parts of it, there it will ſink, the Parts of it which are leſs preſs'd aſcending as that deſcends, and from what has been hitherto ſaid, may be inferr'd the following Propoſitions as ſo many Corollaries.

Coroll. 1. If an heavy Body E, F, H, B, (*Fig.* 4.) lying upon a Fluid A, B, be of an equal Weight with the Air that takes up an equal Space A, H, E, G, the Surface A, B, of the Fluid will retain its Level, as being every where equally preſs'd.

Coroll. 2. If the Body E, F, I, K, (*Fig.* 5.) be lighter than the Air which takes up the like Space, then the ſaid Body, and the Particles of the Fluid under it, will aſcend, till the Aggregate of the Body I, K, E, F, and of the Parts E, F, H, B, of the Fluid ſo aſcending (*viz.*) I, H, B, K, be of equal Weight with the Air that takes up the like Space G, A, H, I, for then the Surface A, B, will be equally preſs'd every where, both in A, H, and H, B.

Coroll. 3. If the Body E, F, A, B, (*Fig.* 6.) be heavier than the Air of a like Bulk, then the Body will ſwim in the Fluid, deſcending ſo far into it, till the Aggregate of the Air G, E, I, K, and the Fluid I, K, A, H, (*viz.*) A, H, E, G, which take up together like Space with the ſaid Body, be of equal Weight with the Body; for the Surface A, B, will become equally preſs'd, both in A, H, and H, B.

Coroll. 4. If the Body E, G, D, F, (*Fig.* 7.) be heavier not only than the Air, but alſo than the Water, or any other Fluid that

takes

takes up the like Space H, C, G, E, then the Body will fink quite to the Bottom C, D, there being nothing to counterpoife or bear it up till it comes to the Bottom. For the Body being fuppos'd to be put on the upper Surface A, B, and to lie upon the Part I, B, thereof, it being heavier than a like Bulk of Air, the Part of the Fluid I, B, D, E, will be more prefs'd thereby, than the other Part of the Fluid A, I, E, C, by the Air, and therefore the Particles I, B, D, E, will defcend. And in like Manner when the Body is come to G, F, it being heavier alfo than a like Bulk A, H, G, I, of Water, it will ftill prefs the Parts of the fluid Water G, F, more than thofe that are under G, H, and therefore will caufe the Parts under G, F, ftill to give Way, till it comes to the Bottom C, D, than the Water of a like Bulk, and fo muft fink according to the Principles of Hydroftaticks aforementioned.

If a Fluid *(Fig. 9.)* particularly Mercury or Quickfilver, contain'd in the Tube C, D, preffes on the Part C of the Surface A, B, more than the Air preffes on the other Parts, C will defcend and the Quickfilver run down out of the Tube, till what is left at C, I, in the Tube preffes C, juft as much as the other Parts are prefs'd by the Air. And then no more will run out of the Tube, becaufe of the equal Preffure in all Parts of the Surface A, B: Where it is to be noted, that this Weight of the Quickfilver C, I, is equivalent to the Weight of a Column of Air extended from the Surface A, B, up to the Top of the Atmofphere, and of the fame Bafis or Diameter of the Tube C, D.

And it is obfervable *(Fig. 10.)* that the Quickfilver will rife up juft to the fame Height in the oblique or floping Tube E, G, as it does in the upright Tube D, C, although the Quickfilver E, F, in the Tube E, G, be more, and confequently heavier than the Quickfilver C, I, in C, D. The Reafon whereof is this, that as much as the Quickfilver E, F, is more than the Quickfilver C, I, fo much greater is the Bafe E, than the Bafe C. This being equal to the Bafe of the Cylinder E, K, wherein the Quickfilver E, H, will be found to be juft fo much as the Quickfilver E, F, by Reafon of the two Tubes E, K, and E, G, being Cylinders of equal Height upon the fame Bafes, and therefore equal to one another: Now it is obvious that fuppofing the Bafe E, to be twice as Big as the Bafe C, and confequently the Quickfilver E, H, in the Tube E, K, or the Quickfilver E, F, in the Tube E, G, to be twice as much as the Quickfilver C, I, in the Tube C, D, it evidently follows that as the Quickfilver C, I, does equiponderate

derate to a Column of Air of the ſame Baſe C, ſo will the Quick-ſilver E, H, or E, G.

Coroll. 5. Upon the ſame Principles, if a Body G, H, I, K, (*Fig.* 8.) be immerg'd into the Fluid, and be of equal Weight with ſo much E, F, G, H, of the Fluid, as takes up the like Space, that is in ſhort to be of the ſame ſpecifick Gravity with the Fluid, then the ſaid Body will ſtay where it is plac'd in the Fluid, without either riſing or ſinking; for the Surface E, I, being equally preſs'd all along, the ſaid Body cannot riſe, and the Surface F, K, being all along equally preſs'd, neither can the ſaid Body ſink.

But if one of the ſaid Fluids be ſpecifically lighter than the other, and conſequently the Bulk G, H, I, K, be lighter than the Bulk E, F, G, H, it evidently follows that the Surface I, K, will be more preſs'd in F, H, than in H, K; and conſequently the Body G, H, I, K, will be thruſt up and riſe higher and higher for the ſame Reaſon, till it comes to ſuch a Situation, as that it is of equal Gravity with ſo much Air (which in this Caſe is ſuppoſs'd to be lighter than the Body) and ſo much of the Fluid as takes up an equal Space with it (as is repreſented in *Fig.* 6.) But laſtly if the Body be of the ſame ſpecifick Gravity with the Air, then it will riſe to the very Top of the Fluid, as in *Fig.* 4. I ſhall not attempt to reduce to Practice all that might be ſaid in the ſeveral Caſes of Hydroſtaticks; but from what has been already noted it is eaſy to account for ſeveral Occurrences that naturally offer themſelves in Fluids, I mean in that Part of Hydroſtaticks that is the Deſign of my preſent Undertaking; and from hence it is eaſy to tell why we don't feel the Weight of a Bucket, and the Water that is in it, when we draw Water, till it begins to riſe out of the Water. Namely becauſe, ſuppoſing the Bucket with the Water in it to be repreſented (*Fig.* 8.) by G, H, I, K, it being of the ſame Gravity with the like Bulk of Water E, F, G, H, the Surface F, K, will be equally preſs'd both in F, H, and H, K; and therefore the Bucket of Water can't deſcend, but is held up by the Water under it, and conſequently the Weight of it is no more felt, than is a Weight which is counterpoiz'd by an equal Weight upon a Ballance: And the ſame holds all the while, the Bucket is drawing up, to the Surface A, B, where it and the Water in it, coming into the Air, ſo much ſpecifically lighter than the Water or Wood &c. of the Bucket, the Air can't ſuſtain it, and ſo muſt be ſuſtain'd by him that draws up the Bucket.

Hence alſo it is eaſy to account how the Weight of any mighty Ship is ſupported by Water, it being of equal Weight

with that of fo much Water as in Bulk is equal to the immers'd Part of her, or (as the learned *Boyle* and from him Dr. *Harris* in his *Lexion Technicum* obferves) to that Part of her Hull which is underneath the Surface of the Sea.

ACCORDING to the fame Principles alfo we may eafily tell why one Liquor will fwim upon another, or remain at Top without mixing, if it be poured on gently; as Oyl in refpect of Water; and Water in refpect of Quick-filver: Namely because Oyl is fpecifically lighter than Water, and Water than Quick-filver.

MOREOVER the Reafon why a Log of Wood that has been fwimming a long Time upon Water, but will fink at laft, is this, (*viz.*) Becaufe fuch a Piece of Wood may be of the fame or greater fpecifick Gravity than Water, fetting afide the Pores of the Wood; but by reafon the Pores of Wood are full of Air, the Air which fills the faid Pores and the Wood together make up one whole, lighter than an equal Bulk of Water, and therefore the Wood will not fink at firft. But after fome Time the Water being got into the Pores, and fo the Air excluded; then the Water in the Pores, and the Wood together, make up one Whole heavier than the Water of a like Bulk, which is double the Quantity of C, I, does but equiponderate to a double Quantity of Air that is to a Column of Air, whofe Bafis E is the double of the Bafis C.

SINCE according to the Rules of Staticks, Bodies gravitate or weigh heavier in a perpendicular, than in any oblique or floping Situation; it may be ask'd why the Quickfilver E, H, gravitating or preffing upon the Bafis E, more than does the Quickfilver E, F, (that being perpendicular to E, this Oblique) the Quickfilver does not defcend lower in the Tube E, K, and higher in the Tube E, G. The Reafon then is this, that as much as E, H, preffes downwards more than E, F, fo much does the force at E, which (arifes from the Preffure of the Air on the other Parts of the Surface A, B, and) fuftains the Quickfilver in each Tube, prefs upwards more in the upright, than in the oblique Tube; and both for the fame Reafon (*viz.*) becaufe the Preffure, whether upwards or downwards, is in the Tube E, K, perpendicular, whereas in the Tube E, G, it is oblique, and therefore not fo great.

NOW the Force at E, which holds up the Quickfilver in the upright Tube, being as to its Effort, fo much greater than the Force at E, which holds up the Quickfilver in the Oblique, as the Weight of the Quickfilver in the upright Tube, is greater than the Weight of

of the other; it follows that the ſaid Force at E, acting upwards according to the Perpendicular E, H, is as able to ſuſtain the Quickſilver in the upright Tube, as is the ſame Force acting upwards according to the oblique Line E, F, to ſuſtain the ſame Quantity of Quickſilver in the oblique Tube, and therefore the Quickſilver in the upright Tube will not deſcend lower by running any of it, out of the ſaid Tube, nor will the Quickſilver in the oblique Tube aſcend any higher by any more running into it; but the ſame Quickſilver (and conſequently Water itſelf) will keep at an equal Height in both Tubes.

And the ſame will hold good as to any other Tube, (or Veſſel) of any other Shape: Namely, the Height of the Quickſilver or Water, will be the ſame in any Veſſel, as it is in a Cylinder of the ſame Height and Baſis with the Veſſel. Thus for Inſtance, (vide *Fig.* 11. of the following Plate) the Height of the Quickſilver is the ſame both in the round headed Tube D, E, H, F, and the ſharp-headed K, L, B, as it is in the Cylinder inſcrib'd inthe former *(viz.)* C, I, or the Cylinder B, L, O, P, circumſcrib'd about the later. For as to the round-headed Tube D, E, H, F, as much of the Quickſilver as lies without the Cylinder C, I, is ſuſtain'd, not ſo much by C, as by the Parts M, I, and N, S, of the Tube's Head, which are under them, and no more of the Quickſilver is properly or directly ſuſtain'd by C, than what lies within the Cylinder C, I, and conſequently the Effect will be the ſame, as if the Quickſilver was put in the Cylinder C, I.

As to the ſharp-headed Veſſel L, B, K, and the Cylinder B, L, O, P, the Quickſilver will likewiſe riſe as high in one as the other; for as to ſo much of the ſaid Veſſel, as allows of a free Aſcent from the Surface A, B, the Quickſilver will there riſe to its juſt Height C, I, for the ſame Reaſon, as it will riſe to the ſame Height in the Cylinder B, L, O, P.

As to the other Parts of the ſaid Veſſel, where the Quickſilver is hindred by the Sides of the Veſſel to riſe up to the Height C, I, as much as there is wanting in the Weight of the Quickſilver, &c. To conclude this Chapter, 'tis from Experiments of this Kind it is demonſtrated that a Ship (Wood being ſpecifically lighter than Water, eſpecially that which is ſalt) will float with great Safety and Pleaſure on the main Ocean; but which by being over-burthen'd, and ſailing into Rivers which are leſs ſalt are apt to ſink; ſo that when I ſpeak of Water I always mean that which is equally heavy, or in plainer Words that I may err in the right

rather than the wrong Side, I would be always underſtood to mean freſh Water, the ſpecifick Gravity whereof in relation to other Bodies will be ſet down in ſome following Chapters.

In relation to Water, that which is ſalt is, as has been before obſerv'd, heavier than that which is freſh; and *Pliny* ſpeaks of certain Rivers, ſuch as the Water of the Lake *Asphaltite*, and that of *Arethuſe*, which runs towards *Syracuſe*, wherein nothing will ſink; and it muſt be noted alſo, that Metals, and heavy Solids, ſink in Water, according to the Figure they have: For Gold, Silver and Copper ſinks not in ordinary Water, if they be beaten out into Plates and thin Leaves; but if it be contracted into a more ſolid Form, it ſinks forthwith to the Bottom.

BOOK. II.

CHAP. XII.

Of the Gravitation of Fluids, according to the honourable and learned Mr. Boyle.

THE Chapter going before, in which the Principles and Problems of Hydroſtaticks are mathematically explain'd, being chiefly deduc'd from *Wallis* and other eminent Writers, whoſe Experiments on this Head are therein ſet down; I have added this other Chapter from the honoured and learned Mr. *Boyle*, in which with more Eaſe yet great Accuracy and Plainneſs he has brought to Light whatever was mathematically, and ſo more obſcurely handled by others.

That admirable Gentleman (who was ſo great an Honour to his Country) conſidering that all Perſons are not acquainted with, and cannot ſo readily digeſt rigid mathematical Demonſtrations, reduc'd the chief of the hydroſtatical Theorems into about eleven

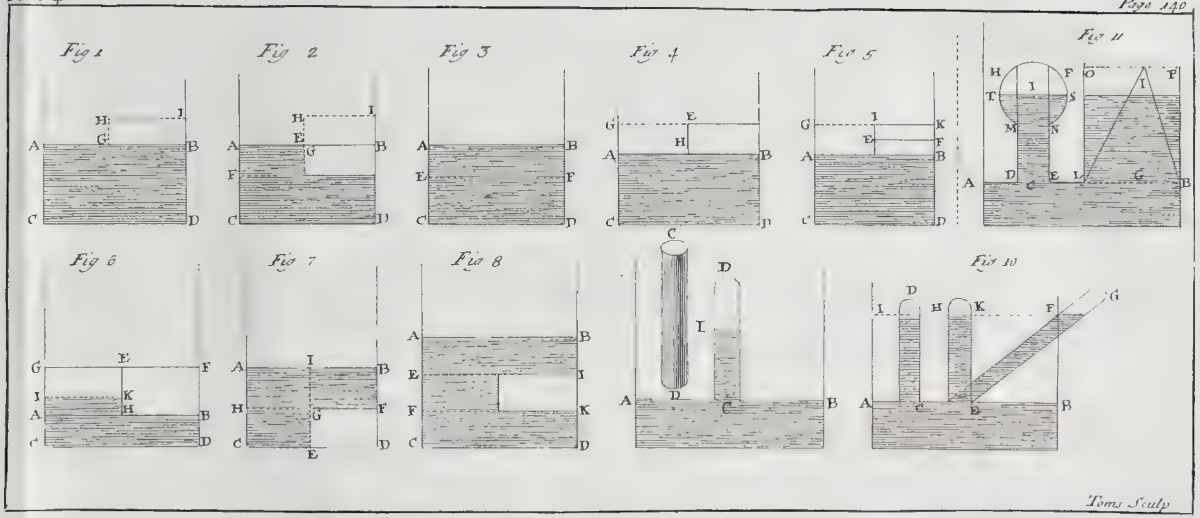


Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8
Fig 10
Fig 11
Toms Sculp

eleven Propoſitions or Paradoxes; a more full Account of which is to be found in a little Treatiſe of his, entituled *Paradoxa Hydroſtatica*, premiſing in the Front of it ſeveral things proper to be known in this ſo curious a Subject, under the Title of *Poſtulata's* or *Lemmatas*.

The firſt is (*vid. Pag.* 7.) that if a Pipe or Tube opened at both Ends, and plac'd perpendicularly to the Horizon, have its lower Orifice under Water, there will be an imaginary Plane parallel in all Appearance to the Superficies of the ſuperior Water, and which ſhall touch that lower Orifice of the Tube.

Secondly, that each Part of this Surface or Plane will be alike preſs'd by the Perpendicular incumbent Water: Notwithſtanding the Opinion of thoſe who hold *that Water will not gravitate on Water, nor Air on Air*; which muſt be granted, ſince the Water being ſuppos'd to be an homogeneous Fluid of the ſame equal Parts, and of equal Gravity every where, and of equal Height above the Plane; there can be no Reaſon why one Part ſhould be more preſs'd than another, it having the ſame Baſe, and the ſame Altitude, and conſequently the ſame Quantity of Liquor preſſing every where one upon another.

Thirdly, that tho' Liquor will keep its former Poſition, yet when there is a greater Weight laid upon any one Part more than there is upon another, then that Part is preſs'd downwards, or otherwiſe made to give Place, and ſlip, on one Side or the other, as is the Caſe when a Stone, or I may add a Piece of Lead or any other Material which is ſpecifically heavier than Water is, ſinks down in it, and tends to the Bottom; becauſe in what Part ſoever the Stone or Lead deſcends, that Part being more preſs'd than the reſt, gives Way to the ſuperior Force of the Stone, and never reſts till it comes to the Bottom.

Again if any Part of this imaginary Surface be leſs preſs'd upon than the reſt, it muſt by that greater Preſſure, be impell'd upwards, till it have an Height equal to ballance the Preſſure made on the other Parts of the Water: Which will appear highly reaſonable to any attentive Conſiderer, and the Truth of which is thus prov'd.

Suppose a ſmall Tube open at both Ends, be plac'd perpendicularly beneath the Surface of the Water in any Veſſel, (thoſe of Glaſs as being tranſparent are the beſt; becauſe the Aſcent of the Liquor will be the more viſible) then will the Water by the known Laws of Hydroſtaticks riſe in the Tube as high and a little higher than the Surface of the Water without: But if you gently

pour

pour Oyl of Turpentine or any other Liquor (which will not incorporate with the Water) upon that which is contain'd in the Veffel; you will fee, that as the Oyl grows higher and higher on the Surface of the Water, and preffes confequently more on it, fo will the Water rife in the Orifice of the Tube, and defcend again proportionably as the Oyl is taken off, which plainly proves that the Weight of the Oyl preffing more on the Surface of the Water without the Tube, than the bare Air can do within it, forces up the Water fo high in the Tube, till the Cylinder of Water within the Tube, gravitates as much on that Part of the Water under the Orifice of the Tube, as the Air, Oyl and Water together do on all the others without it.

I SHALL not, in the fhort Compafs I propofe to allow my felf in this Chapter, expatiate on all the other Parts with which the honoured and very learned Gentleman before mention'd introduces his preliminary Difcourfe, but come to the Practice it felf.

PROPOSITION. I.

That the upper Parts of all Fluids, as Water &c. *do prefs upon the lower.*

PROVIDE a glafs Jarr, fuch a one as is feen *Fig.* 1. in the following Plate; fill it with Water near full, as up to A, B; then take a glafs Pipe or Tube open at both Ends, and dipping the lower End into Oyl of Turpentine, you may, by ftopping the Top with your Finger, fufpend as much of the Oyl as you pleafe in the Tube: This done move the Tube into the Glafs of Water, and thruft it down till the upper Surface of the Oyl in the Tube be near as low as the upper Surface of the Water; and when you take your Finger from the Top of the Tube, you will fee the Oyl will not run out at the lower Orifice of the Tube; nay if you thruft the Tube lower down into the Water, that Liquor will rife up in the Tube and bear up the Oyl above it; but if you raife the Tube up fo, as that the upper Surface of the Oyl in it be confiderably higher, than that of the Water, the Oyl will drop out of the Tube, and rife up to the Top of the Water. The Reafon of which is this; when the imaginary Surface G, H, on which the End Q, of the Tube B, Q, refts, is as much and no more prefs'd upon, by the Oyl, in the Pipe, than the other Parts of that Surface are by the Parts of the Water which are perpendicularly incumbent on them; then there is an Equilibrium be-

between the Oyl and the Water, and ſo the Oyl can't run out; and when you ſink the Tube down as low as O, the incumbent Water gravitates more on the Surface or Plane E, F, than the Oyl in the Tube doth on the Part under it; and conſequently the Water will be forc'd up into the Tube, and bear the Oyl above it, and the Water will riſe ſo high, as that it, and the Oyl together in the Tube, N, O, do gravitate as much on the Surface E, F, as the other incumbent Parts of the external Water do: But if you raiſe the Tube up into the Poſition R, S, the Oyl in it, preſſing more on the imaginary Surface I, K, than the incumbent Water does on any other Part of it, the Oyl muſt run out, till ſo much deſcend out of the Tube, as will bring the Weight of the Oyl, to an Equilibrium with that of the Water, which demonſtrates the Truth of this Propoſition. * For if the Experiment be try'd in any two other Liquids that won't mingle and incorporate with one another, it will have the ſame Effect, provided the Pipe be not too large.

PROPOSITION. III.

That a lighter Fluid may gravitate or preſs upon a heavier.

FILL a Jarr or Veſſel with Oyl of Turpentine inſtead of Water, and then place in it a Tube of the ſame Dimenſion as the former, in which there is ſuſpended a Column of Water in the ſame Manner as you did before that of Oyl; and you will find that tho' the Water be heavier, than that of the Oyl of Turpentine, yet if you don't take away your Finger, from the upper Orifice, till ſuch Time as you have ſunk the Pipe ſo low, as that the upper Surface of the Water in it, be a little below the Surface of the Water of the Oyl in the Glaſs; then I ſay, that on taking away your Finger you will find the Water in the Pipe will not run out: That if you ſink the Tube lower, or pour more Oyl into the Veſſel, the Oyl will riſe up in its lower End; and that if you raiſe it higher, then the Water will drop or run out, and fall to the Bottom of the Veſſel, which plainly ſhews that one Liquor which is ſpecifically lighter than another may by its own Gravity (being when compos'd of a greater number of Parts join'd together) preſs upon one which is more heavy.

* To wit that contrary to what the *Peripateticks* have aſſerted, *that Water does not gravitate on Water, nor Air on Air*; yet here it is plain *that the upper Parts of all Fluids do gravitate or preſs upon the lower.*

AND

And agreeable to the Explication of this, as well as the foregoing Experiment, it is; that there (I mean in the firft) the Superficies of the Oyl in the Glafs was always higher than the Superficies of the Water without it, the Oyl which was the lighter Liquor requiring the Height to be greater on Account of the Equilibrium; fo in the prefent Experiment the Superficies of the Liquor in the Tube was always lighter than the Oyl which was without it; for if in the imaginary Plane E, F, (*vid. Fig.* 2. *Tabula feq.*) the Cylinder of Water I, G, is at reft in the Tube I, H, it will on Account of its greater Gravity prefs upon the Part I, and the diftill'd Oyl (K, E, F, L,) which is a lighter Liquid, then it can prefs upon the other Parts of the fame fuppos'd Plane, E, F, although it fhould raife the Oyl to a Height greater than its own.

But this Propofition is confirm'd by our oft-quoted honourable and ingenious Author by another Experiment, into a long glafs Tube feal'd up at one End, and whofe Bore is about half an Inch; let there be poured a Quantity of Water, and then having a fmall glafs Bubble about the Bignefs of a Pea, with a very fmall and flender Stem, (as is feen in *Fig.* 3. *Tabula feq.* aforefaid) let this Bubble be fo exactly poiz'd by forcing Water into it, that tho' it fhould not fink in a Veffel of Water at firft Tryal, yet a little more Weight would make it do fo.

This Bubble being put into the glafs Pipe will fwim on the Top of the Water contain'd in it; but when Oyl of Turpentine is pour'd very gently on the Water which is in the Pipe, and till it has attain'd to a convenient Height above the Surface of the Water, it is vifible that the Bubble which before fwam on the Surface of the Water, will fink then down to the Bottom, and ftay there, fo long as the Oyl was kept upon the Water; but if either the Tube was any Way very much inclin'd, or if the Oyl by a Siphon or any other Inftrument was drawn of, then the Bubble will rife to the Top again.

The Reafon of which is plainly thus, that when the Oyl is poured on, that did (tho' a lighter Fluid than Water is) by its own proper Gravity, (confider'd as a larger compounded Body) prefs upon the incumbent Water, and by that Means did force fome of it to enter in at the little Stem of the Bubble; which by that Means being rendred more ponderous in the Whole, did fink to the Bottom; but when the direct Preffure of the Oyl upon the Water was taken off, by inclining the Tube, or remov'd by drawing off the Oyl quite, the Air which is in the Bubble before will by its own

own Elaſticity (of which more will be ſaid elſewhere) force out the newly admitted Water again, and ſo reduce the Bubble to its former Degree of Gravity in ſuch a Manner as that it would riſe in the Water as before.

It was found alſo that pouring on more Water will produce the ſame Effect, if by a Wire thruſt down to, and then kept at the Bottom of the Tube; for tho' it would readily riſe again on the Removal of the Rod or Wire, when no more Water was poured into the Tube; yet that if the Wire kept the Bubble at the Bottom till more Water was poured in, to the Height of about two or three Foot, the Bubble would then on the Removal of the Wire ſtay there, and not riſe at all till the ſame Quantity of Water was taken out which was before added.

This I think may truly be ſaid to illuſtrate and prove the firſt Propoſition, *that the upper Parts of all Fluids do preſs or gravitate on thoſe which are under*; as alſo this 2. *(viz.) that a lighter Fluid may gravitate or preſs upon a heavier*, which I take to be one of the nobleſt and moſt uſeful Theorems in Hydroſtaticks; becauſe from hence it is that Air tho' 800 Times lighter than Water is demonſtrated to gravitate thereon, and raiſe it to a determinate Height; for tho' the Particles, of which it is compos'd, be as it were imperceptible, yet when taken altogether as a Body making up that which we call the Atmoſphere, the Bulk of it is regularly ponderous, and by its Preſſure effects all thoſe things which by the preciſe Laws of Hydroſtaticks we diſcover; but of this more is ſaid in its proper Place.

PROPOSITION III.

If a Body contiguous to Water be altogether, or in Parts lower than the upper Surface of the Water, the lower Part of the Body will be preſs'd upwards by the Water which toucheth it beneath.

The firſt experiment ſhews that the Oyl of Turpentine was kept in an open Tube from deſcending or running out of it, by the Preſſure upwards of the Water in its lower Parts, and by the laſt Propoſition it appears that Oyl (tho' a lighter Fluid than Water) could preſs upwards, or keep Water; a Fluid ſpecifically heavier than Oyl is, ſuſpended in an open Pipe.

But in order to eſtimate how much the Preſſure of the Water againſt the lower Parts doth amount to, let it be ſuppos'd that

any

any other Kind of Liquid which is heavier than Water, as Oyl of Cloves, Cinnamon, &c. were taken into a Tube, and then that Tube were as in the former Caſes, immers'd or ſunk into a Veſſel of Water, and there plac'd ſo ſhallow, that the Oyl on removing of the Finger from the Top of the Tube, would drop out. The Drop G, *(vid. Fig.* 4. of the Plate following) being ſpecifically heavier than Water would, by the 3 Poſtulata's juſt laid down, ſink to the Bottom, but not ſo quickly as it would in the Air; and ſince if it were a Matter equiponderant to Water as Wood and ſome other things are, it would not ſink at all, or but juſt emerge: It now ſinks by no greater Degree of Gravity, than that by which it ſurmounts a Quantity of Water equal to its Bulk, and conſequently it would loſe in the Water juſt as much of the Weight as it would have in the Air, as ſo much Water as is equal to it in Bulk, if weigh'd in the Air alſo, would amount to; which is another phyſical Demonſtration of theſe noble and uſeful Theorems in Hydroſtaticks. To proceed,

The Preſſure of Water alſo againſt the lower Parts of any immers'd Body, is confirm'd by attending to the Reaſon why Oyl ſpecifically lighter than Water doth riſe out of it, and ſwim as it were upon it; which is this, that there is a greater Preſſure or Weight on every other Part of the imaginary Surface of the Water (as ſuppoſe I, K, *Fig.* 1. of the Plate following) than there is on that on which the riſing Body leans; and conſequently produces an Equilibrium in the Fluid; the Parts immediately under the riſing Body being preſs'd by the reſt every Way, muſt continually force it upwards till it attain the upper Surface of the Water: For the immerging Body is continually preſs'd upon by the two Columns of Water, one bearing againſt its upper, and the other againſt its lower Parts; the Length of both which being to be accounted from the Top of the Water, that which preſſes on the lower Part, will be the longer by the Thickneſs of the aſcending Body, and conſequently over-ballance it by the Weight of as much Water as will fill the Space that the Body takes up: Wherefore the greater Diſparity there is between the ſpecifick Gravities of Water and the emerging Body, and the larger the Particles are which emerge, the ſwifter they will aſcend, which will be a great Aſſiſtance in the accounting for the Truth of that Problem, the Solution of which is propos'd by Writers in Hydroſtaticks *(viz.)* how it comes to paſs, that if any cylindrick Staff be cut into two Parts, one half whereof is doubly as long as the other, and both being detain'd under Water of an equal Depth, but being let go at

at the ſame Time, and ſuffer'd to emerge, the largeſt will aſcend faſter than the ſmall one.

Suppose one of theſe Bodies as O, P, *Fig.* 4. *(Tabula ſeq.)* be two Foot long, but the other Q, R, but one Foot, and that the lowermoſt Superficies of them both be in the ſame imaginary Plane parallel to the uppermoſt, and three Foot Diſtance; the Caſe muſt be thus, the longeſt will come firſt to the Top, becauſe that the Columns of Water which preſs againſt the lower Ends of both being equal, but that Preſſure ſhorteſt which preſſes upon the upper End of the longeſt Piece; it muſt be leſs preſs'd downwards than the other Piece is, and ſo by the general Preſſure upwards will riſe the faſteſt; and from hence may be probably deduc'd (as our ingenious Author Pag. 68 of his Hydroſtaticks in the *Latin* Edition has it) that which is often obſerv'd in the Diſtillation of the Oyls of Aniſe, Clove, Gillyflowers, and a great many other aromatick Vegetables in an Alembick by the help of Water, which having very minute Corpuſcles, either lighter or heavier in Specie than the Liquor they are mingled with, and when the Heat is withdrawn from them, may be kept there a good while without riſing to the Top or ſinking to the Bottom, their Thickneſs being indefinitely made ſmall, the Difference between the two Columns beforemention'd will be ſo too, and conſequently neither of them can much over-ballance one another; and from hence may be prov'd what is affirm'd by *Archimedes* and other Writers in Hydroſtaticks, that any Body which is equiponderate or of equal Weight in Specie to Water, in whatſoever Place it is put, it will there remain quiet.

And that we may carry the Matter farther, if the Drop G, *Fig.* 3. (*Tabula ſeq.*) aforeſaid was any Material not heavier than Water, it would neither ſink lower nor riſe higher; it would follow from the ſame Rule, that if it was heavier in Specie than Water, the Fall or ſinking would be according to its Gravity, and that it would loſe that Weight in Water which it has in the open Air, which is one of the phyſical Reaſons of that great Hydroſtatical Theorem, which is ſo ſolidly and clearly demonſtrated by the moſt learned *Stevinus* himſelf.

This ingenious Propoſition of Bodies ſwimming is very clearly taught and prov'd by the ſubtle *Archimedes* and his Commentators in his two excellent Books *de Inſidentibus Humido*; and from hence may be accounted the Quantity of any floating Body which is beneath the Surface of the Water, *which is always in Bulk equal to as much Water as the whole floating Body doth weigh;* for this

floating Body doth by its lower Parts preſs upon the ſubjacent Parts of the imaginary Surface of the Water X, W, (*Fig.* 5. *Tabula ſeq. prædict.*) juſt as much as the Columns of Water to the Altitude A, X, or B, W, do on all the other Parts; that is juſt as much as the Water would do if it were in the Space which the immers'd Part takes up, or as much as a Quantity of Water equal in Bulk to the immers'd Part could do.

FROM hence is clearly demonſtrated that the Weight of any Ship, being the ſame with that of ſo much Water, which is in Bulk equal to the immers'd Part of her, or to the Part of her Hull which is underneath the Surface of the Sea, all which was accurately diſcover'd by our moſt noble Author, who took a broad ſhallow Veſſel and fill'd it almoſt to the Top with Water, and then plac'd it in a glaſs Tumbler or ſhort drinking Glaſs; and to make it reſemble a Ship, he fitted a wooden Deck with a Maſt &c. to it; and then he ſunk it by ballaſting it with Sand, and made it in the Language of Seamen draw as much Water as he thought fit: Then by exact Remarks he diſtinguiſh'd how much the Water which was in the containing Glaſs roſe on the Sides of the Veſſel: This done he took the Tumbler out and wip'd it clean, and then weigh'd it, and ſo found a Quantity of Water exactly equal to that Weight; and from hence is deduced an Argument in Favour of the learned *Stevinus*, who in ſome of his Hydroſtatical Propoſitions deduces it as a Corollary, * *That a whole Ship and all things which belong thereto, or lie upon it preſs neither more nor leſs, on the Bottom on which they ſwim, than ſuch a Mole or Column of Water, which is equal to that Part of the Ship, which was below the Superficies of the Water does.*

BUT this muſt be ſaid only of Salt or Sea-water which is ſpecifically heavier than that which is freſh, it having been obſerv'd by ſome Ancients as well as Moderns, that Ships which have return'd heavy laden home, and have drawn Water nearly up to the Deck, have when they have come into freſh Water have ſunk; and this is the Reaſon why all good Ship-builders are ſo very exact in their Calculations of the Number of Tunns, every Veſſel is fit to carry.

* Navis tota, omniaque, quæ ad eam pertinent, vel ei incumbent, non magis nec minus premunt Fundum, cui ſupernatant, quam tanta Moles aquæ, quanta æqualis eſt iſti Navis parti quæ eſt infra aquæ Superficiem (vid. Scholium in *Boyle*'s Paradoxa Hydroſtatica) Pag. 78. of the *Latin* Edition.

PROPOSITION IV.

That in the Aſcenſion of Water in Pumps &c. *there is nothing requir'd to the raiſing of Water but the juſt Weight of ſome other external Fluid.*

THIS Aſcent of Water in Pumps having been already from the Propoſitions of the learned *Wallis* and others ſo fully explain'd, I ſhall be the ſhorter in my Account of it in this Place; becauſe it is demonſtrable by this one eaſy Experiment of our learned Author.

TAKE a ſingle glaſs Tube, ſuch as is us'd in the firſt Experiment, about an Inch high, deeply ting'd with the Infuſion of Brazil-wood, Cochineel, *&c.* that the Experiment may be more plain, (then ſtopping the upper End with your Finger) place it in a Glaſs fill'd with the ſame tinged Liquor, and that ſo low, that the upper Surface of the Liquor in the Tube be at leaſt an Inch below that of the Liquor of the Veſſel; then pour on Oyl of Turpentine for about 3 or 4 Inches Height above the Water in the Veſſel, and you will ſee on the Removal of your Finger from the Top of the Tube, that the tinged Water will be rais'd or impell'd upwards near as high as the Surface of the Oyl.

NOW in this Experiment there is no Colour or Reaſon to be aſſign'd to the *ancient pretended Abhorrence of a Vacuum which was ſuppos'd to be in Nature*, as the Cauſe of the Aſcent of this Water; for the Tube is full of Air, and the external Air hath a free Ingreſs into it: But the plain Reaſon is this, that there being a greater Preſſure made by the Oyl and Water together on the imaginary Plane, which paſſes by the lower Orifice of the Tube without the Tube, rather than within it, (for within there is a Preſſure only of an Inch of Water, and of a Column of Air) the Parts of the Water at the Bottom of the Pipe muſt be thruſt upwards into it, till it riſe ſo high as to gain in Equilibrium with the reſt; and this demonſtrates the Riſe of Water in Pumps where the external Air preſſing every where on the Surface of the Water in the Well, but not on that which is within the Pump, the Force of which is loſt by the Cloſeneſs as well as the paſſing and repaſſing of the Sucker; which is therefore with ſoft Leather made ſtanch on Purpoſe; on the raiſing of the Sucker the Water muſt follow if the Pump be good; becauſe the Weight of the whole Atmoſphere preſſes upon the Surface of the Water in the Well, (but

(but not at all within the Body of the Pump) and ſo raiſes or forces it up into the Cavity thereof; and that this Preſſure of Air is the Cauſe of the Water's Aſcent, is more than probable; becauſe no Pump can ever raiſe Water above 33 or 34 Foot (as is elſewhere obſerv'd) which is found to be exactly agreeable to the different Gravity of Air and Water, allowing for the great Height of the Atmoſphere.

I might in this Place have expatiated on the different Heights, Liquids of different Weights, as Oyls, Mercury, Wine and others will riſe, which is indeed no other than according to the ſpecifick Gravities of each, but that will more properly fall in, in another Place.

PROPOSITION V.

That the Preſſure of any external Fluid is able to keep up any heterogeneous Liquor of different Kinds, ſuſpended at the ſame Height in ſeveral Tubes or Pipes, tho' they be of different Diameters.

TAKE a wide-mouth'd Glaſs (ſuch as *Fig.* 7. in the Plate following) of a convenient Depth, and put into it a ſufficient Quantity of Water well ting'd with Brazil or any colour'd Water, then fit to it a Cover of Cork through which bore with a red hot taper Iron ſeveral round Holes to admit Tubes of different Bigneſs or Sizes.

LET theſe Tubes ſtand nearly upright in the Veſſel, and each of their lower Orifices below the Surface of the Water; then at a Hole purpoſely left for it, pour in gently by a glaſs Tunnel a good Quantity of the Oyl of Turpentine, and you will plainly ſee the ting'd Water riſe equally (i. e. to equal Height) in all the Tubes, tho' of very different Bores and Sizes.

LET E, F, (*Fig.* 7. *prædict.*) repreſent the Surface of the Water in the Veſſel, when the Oyl (being not of a Nature to mix and incorporate with it) will ſwim at Top, and with an equal Gravity preſs upon all Parts of the Surface of the Water; and conſequently will raiſe or preſs up the Water in the Tubes, till it come near to the ſame Height in them, as the Oyl is at in the Glaſs, to bring the Liquors to a Ballance. But there can be no Reaſon why the Water (being of an equal ſpecifick Gravity) ſhould riſe higher in one Tube than another; becauſe the Oyl preſſes uniformly and equally on all Parts of the Surface of the Water; and conſequently can raiſe the Water no higher in the ſame Tube, than in the

large one, for if it should do so, the Water in the small Tube must be of a much greater Length than the corresponding Column of Oyl, whose Diameter is equal to the Orifice of that Tube; and which keeping it up by equiponderating with it, does require: But then it must be heavier than it, and so would sink down and drive the subjacent Water away to make Room for its Descent: Wherefore no Cylinder of Water in any Tube can be higher than an equal Cylinder of Oyl that bears or buoys it up; and this being the Case with them all, they must be of the same Height; that is, the Water will rise in one Tube as well as another, be their Bores never so different, and the Reason is, because one is born up by a corresponding Column or Cylinder of Oyl, whose Diameter is the same with the Tube.

NEVERTHELESS this does not contradict the Rise of Liquids in Capillary Tubes, when press'd by Fluids of different Gravities, as before set down on the Original and Rise of Springs; nor yet the Spouting of Liquids in open Air, which always rises the highest in Proportion, as they are nearer or farther off from the Center of Gravity; but of this no more at present.

PROPOSITION. VI.

IF a Body be plac'd under Water, with its uppermost Surface parallel to the Horizon, the direct Pressure which it sustains is no more than that of a Column of Water, having the horozontal Superficies of the Body for its Basis, and the perpendicular Depth of the Water for its Height. And if the Water which leans on the Body be contain'd in Pipes open at both Ends, the Pressure of the Water is to be accounted for by the Weight of a Pillar of Water, whose Basis is equal to the lower Orifice of the Pipe, and its Height equal to a Perpendicular reaching from thence to the Top of the Water, though the Pipe be much inclin'd; nay, or tho' it be never so irregularly shaped and much broader in some Places than at the Bottom.

THE learned *Stevinus* (as we have it from Mr. *Boyle*, p. 99. of his *Paradoxa Hydrostatica*) in the 10th Proposition of his Elements of Hydrostaticks, after he had propos'd the former Part of this Paradox, adjoins a Demonstration to it in the following Words:

IT being first suppos'd that A, B, C, D, (*Fig.* 5. of the following Plate) is a solid rectangle Figure, whose Base E, F, is par-

parallel to the Horizon, and whoſe Altitude G, E, is a Perpendicular let down from the ſupreme Superficies of the Water to the Bottom.

If the Bottom E, F, ſhould be loaded with a greater Weight than is the Weight of the Water G, H, that Superpondium or over Ballance muſt neceſſarily ariſe from the Contiguous Water; there it is poſſible it may riſe from the Water A, G, E, D, and H, B, C, F, which being granted, the Bottom D, E, will in like Manner rather have the incumbent Weight on it ſelf, on Account of the Neighbouring Water, than the Weight of the Water A, G, E, D; and when the Reaſon in all theſe three Caſes is the ſame, the Baſe F, C, ought to ſuſtain a greater Weight, than the Baſe of the Water H, B, C, F; wherefore the whole Bottom or Baſe D, C, will have a greater Weight incumbent on it, than that of the whole Water A, B, C, D, which nevertheleſs (the Body A, B, C, D, being rectangular) was abſurd; and by the ſame Method of Reaſoning ſhall be prov'd, that the Baſe F, C, does not ſuſtain leſs Weight than the Baſe of the Water G, H, E, F; and therefore as it does not ſuſtain neither more nor leſs Weight, it is neceſſary it ſhould ſuſtain ſo much of the preciſe Weight, as the Column of Water G, H, F, E, amounts to.

This Method of *Stevinus*, the learned *Boyle* found to be not exactly agreeable to Truth, and therefore he invented ſeveral of his own; for the firſt of which take the following Directions.

Prepare a ſlender glaſs Pipe of an equal Bore, turn'd up one End like that in Figure 7 Plate the following; dip this Tube open as it is at both Ends into Oyl of Turpentine, till the Liquor be riſen up to two or three Inches in the longer Leg, whoſe upper Orifice then ſtop with your Finger; and then remove your Tube into a Glaſs of Water, and hold it ſo that the Surface of the Oyl in the longer Leg of the Pipe be but a very little higher than that of the Water; and then if you take away your Finger which ſtopt the Pipe, you will ſee the Oyl ſtill keep its Station, and not at all, at leaſt very little, riſe or fall; but if you ſink the Tube lower, the Oyl will riſe, and if you riſe the Tube higher, the Oyl will run out at the lower End; from whence it appears, that of all the Water in the Glaſs no more preſſed on the Orifice of the Pipe, than a Cylinder equal to it in Diameter; and in Length equal to the Diſtance which is between the Orifice of the Pipe and the Top of the Water, (as may be alſo eaſily found, if you make a Siphon whoſe ſhorteſt Leg ſhall be long enough to counter-

counterpoize ſuch a Cylinder of Water as will counterpoize the Oyl in the longer) for when by raiſing up the Pipe, you ſhorten that Cylinder, the Oyl will run out: As when by ſinking it lower, and ſo lengthening the Cylinder of Water, the Oyl will be forc'd up higher into the longer Tube.

By Experience alſo it will be found, that this Propoſition will hold good, whatever the Figure of the ſhorter Tube be, whether opening broad like a Tunnel by Degrees, or whether it have a ſphærical or otherwiſe figur'd Cavity, of conſiderable Dimenſions in the middle of it.

For the honourable and learned Author, whom we can never mention but with Admiration, on account of his many excellent Qualifications, found by providing a Siphon of that *(Fig. 8. Tabula ſeq.)* and pouring in Mercury, till it reach'd up to the Bottom of the globular Part of the ſhorter Leg, and to an equal Height in the longer Leg of the Siphon, that if he poured in Water at the Top of the longer Leg, it would drive up the Mercury into the Ball of the ſhorter, and more than half its Cavity (which it would have filled quite had the other Leg been long enough) and that this Ball in the middle of the ſhort Leg, tho' it contain'd a very great Weight of that fluid Mercury, did no more hinder it from riſing to its due Height, according to the different ſpecifick Gravity of thoſe two Liquors, Water and Mercury, than if the ſhorter Leg had every where been of the ſame Dimenſions with its upper Orifice D; for the great Quantity of Mercury which was forc'd up into the Ball, was there in a good Meaſure ſupported by the Bottoms and Sides of it, and no more gravitated on C, than what lay perpendicularly over it, between B and C.

And farther he took (that he might the better make out the Truth of this Propoſition or Paradox) three glaſs Pipes L, O, G, of ſuch irregular Shapes as is ſeen *Fig.* 10. (*Tabula ſeq.*) and theſe by Holes made on Purpoſe for them in a Covert of Cork, he placed obliquely within a glaſs Veſſel fill'd with Water up to A B, and then by the Help of the Tunnel I, he gently poured in Oyl of Turpentine, till its upper Surface reach'd to F E; which Oyl he found did by its Preſſure, on the Surface of the Water, raiſe it up to an equal Height, in all the three Pipes.

And this which follows, very well agrees with that which goes before. Let there be procur'd three Tubes as is ſeen in *Fig.* 11. *Tab. ſeq.* of an irregular Figure; the Angles of one of which ſhall be acute as is N°. (1.) another of a Helix or ſpiral Line, Shape ſuch as is N°. (2.) and the other of an irregular curve Figure, as

is N°. (3.) ſome Parts whereof are circular, others direct, &c. and let them be fill'd with Oyl of Turpentine, which ſhould be preſs'd down to a convenient Depth under Water, and there ſtopt up (as has been often taught) we have found that according to this Propoſition, the Superficies of the Oyl in the Tube was higher than the Water which was without; the ſpecifick Gravity of one being more than the ſpecifick Gravity of the other: But what was remarkable in this, and the other Experiment was, that tho' the Bottoms of the Tubes were irregular, one broader, the other longer, one ſtrait and the other circular; yet the Oyl aſcended to its due Height, according to the Preſſure it receiv'd from the Atmoſphere.

THE moſt learned *Stevinus* (as our noble Author in his *Scholium* on this Paradox, Pag. 113. has it) ſubjoins ſome Conſectaries, the Truth of which were more doubtful than his Theorems; on which Account Mr. *Boyle* devis'd another Experiment, to confirm the Truth of what he had before aſſerted.

HE order'd a Tin or lattin Veſſel to be made in the Shape of that *(Fig. 12. Tabula ſeq.)* which had a looſe Bottom C, D, made of a flat Piece of Wood cover'd with a ſoft Piece of Bladder, and greas'd on the lower Sides near the Edges, that ſo leaning on the Rim of Wood G, H, contiguous every where, to the Inſide of the Latton, it might eaſily be lifted off from it, and yet lie ſo cloſe upon it at other Times, that the Water ſhould not get between them; to the middle of the looſe Bottom was alſo faſtned a long String, that came up through the Body of the Pipe A, B.

THE Inſtrument thus fitted, there was Water poured in at A, which preſs'd againſt the falſe Bottom C, D, and kept it ſo tight down that no Water ran out. When the Veſſel and Pipe were both fill'd with Water, the upper End of the String K, I, was faſtned to the Beam of a good Pair of Scales, and then as much Weight was put into the oppoſite Scale, as did lift up the falſe Bottom C, D, from the Rim G, H, and ſo let out the Water; and this Weight he found to be conſiderably more than what would have ſerv'd to have lifted up as much Water as that Veſſel did contain, had it been in an open one of the common Shape: But he neither ſets down the Meaſure of the Veſſel, the Height of the Tube, nor the Weight which was requir'd to raiſe the Bottom; but ſays, that *Wallis* himſelf calls in Queſtion the Truth of the Paradox of *Stevinus*, which is more fully explain'd by *Monſieur Varignon* in the Memoirs, Mathematiques & de Phyſique for the Year 1692. Pag. 12.

PRO-

PROPOSITION VII.

That a Body immers'd in a Fluid, ſuſtains a lateral Preſſure from the Fluid, which alſo encreaſeth as the Body is plac'd deeper beneath the Surface of the Fluid.

ALTHO' ſays our noble Author, I am not to wonder that this Propoſition ſhould ſeem a very great Paradox to moſt Readers, yet I hope nevertheleſs, that I can evince and make plain the Truth of it, by a very great Number of Methods; eſpecially one which is very ſimple and eaſy, and which here follows.

TAKE a ſlender glaſs Tube, and let it be bent ſo near the Bottom (*vid. Fig.* 13. *Tabula ſequente*) as that the lower Part F, G, may very nearly make a right Angle with the other Part E, F: Dip this Pipe or Siphon into Oyl of Turpentine, and take up about three or four Inches of it in the Pipe, which you may keep there by applying your Finger to the upper Orifice.

THIS done move the Siphon into a Glaſs of Water and place it ſo there, that the longer Leg may ſtand perpendicularly to its Surface, and that the other lower Leg may be ſo far below the Surface of the Water, as that the upper Surface of the Oyl in the longer Leg, be but a little higher, than that of the Water in the Glaſs; for then if you remove your Finger from the Top, the Oyl in the Tube will very little if at all change its Station; which ſhews plainly that there is a lateral Preſſure, againſt the Oyl at the lower Orifice G, which hinders its running out, tho' preſs'd by the Cylinder of Oyl contain'd in the perpendicular Leg; and if you raiſe the Pipe up higher (keeping it ſtill in its perpendicular Poſture) the Oyl will drop out; ſo if you ſink it lower the Water will get in at G, and force the Oyl all out, of that Leg G, F, and raiſe it proportionably in the perpendicular one E, F; nay if you thruſt it low enough, the Water will riſe up into the longer Leg and bear the Oyl above it; which laſt Circumſtance proves that the Water has a lateral Preſſure againſt itſelf, as great as the perpendicular one from above, ſince that only can force the Water upon it to the perpendicular, and this is a plain Demonſtration of the Gravitation or lateral Preſſure of ſeveral Fluids one upon another, or of any one of them upon itſelf. To proceed,

IF alſo keeping the Tube at the ſame Depth you turn the horizontal Leg here and there, or place its Orifice G, in any Part of the imaginary Plane F, G, the Oyl will keep its former Station

in the Tube, and neither riſe nor ſink; which ſhews that this lateral Preſſure is equal, and uniform, in all Places or Parts of a Veſſel of Water, at the ſame Diſtance from its Surface; and I may add, the greater the Diſtance the Bottom is, from the Surface, by ſo much greater is the Preſſure, which will more fully be demonſtrated when we come to ſpeak of ſpouting Liquids. And to go on,

THE Truth of this Paradox or Propoſition is more amply illuſtrated by the following Experiment.

TAKE a ſmall bubble Glaſs X, of the ſhape of that (*Fig.* 14, *Tabula ſequente*) with a very ſlender Neck, and ſo well poiz'd as that it will juſt float in the Water and no more, (which being provided) was put into a wide-mouth'd glaſs Veſſel, near fill'd with Water, and there left to float, on the Surface of that Liquor; then a Cover or Stopple of Cork, was well fitted to the Mouth of the Glaſs, and was thruſt hard into it, after which there was a Hole burnt with a hot Iron, run through the middle of the Cork, into which was put a long ſlender glaſs Pipe, reaching a good Way into the Glaſs, and ſtanding perpendicular to the Surface of the Cork.

ALSO in another Part of the Stopple, was another Hole burnt, and into that was fitted another glaſs Tube which lay ſloping, but yet reach'd a pretty Way down below the Cork; the upper Orifice of this ſloping Tube was well ſtopt with Cement, and in the ſame Manner were alſo all the Junctures between the Cork and the Glaſs, and between the Tubes and the Cork, carefully ſtopt.

THIS being all done, the Veſſel was inclin'd ſeveral Ways, ſo that the Bubble X, might get as far as it could from the Pipe; and the more Water being poured in at the upper Orifice, of the open Pipe E, F, till it reach'd to a good Height, as ſuppoſe to K, in the ſaid Tube, the Bubble X would preſently ſink to the Bottom of the Veſſel, and there continue as long as the Water was continued at the ſame Height, in the Tube E, F; now this proves that the Preſſure of the Matter, contain'd in the Tube E, F, doth not only affect the Parts of the Water immediately ſubjacent thereto, but alſo thoſe which are more remote from it; nay and above it, ſince it could force the Water into the Bubble X, and ſo make it ſink, tho' it lay not near the Orifice F, of the open Tube.

PROPOSITION. VIII.

That Water may be made to depreſs a Body lighter than itſelf, as well as to buoy it up.

As wonderful as this Propoſition may ſeem to thoſe who are prepoſſeſs'd with Notions concerning Gravity and Levity, there is not wherewithal that thoſe can wonder at who have experienc'd what has been already deliver'd on this Head; for when the ſuperior Parts of Fluids, gravitate on thoſe which are under them, and on other Bodies which lie again under them, and when any Body is unequally preſs'd by others, heavier or lighter than themſelves, it neceſſarily follows that it muſt be drove from that Place where it is moſt preſs'd, into that which is leaſt; if any Portion of Oyl in this Operation is ſo expos'd to Water, that Water may preſs its ſuperior Superficies.

Take a ſlender glaſs Siphon E, F, G, H, (*Fig.* 15. *Tabula ſeq.*) whoſe ſhorter Leg G, H, ſhall be about 3 or 4 Inches long, and turn'd up as near as can be parallel to the longer E, F, which being dipt in Oyl of Turpentine till the Oyl has fill'd the ſhorter Leg, and roſe to an equal Height in the longer.

Then the Orifice E, being ſtopt with the Finger, the Pipe may be mov'd in a Glaſs of fair Water, till the Surface of the Liquor be about half an Inch above the Surface of the Oyl, in the Siphon; and then the Finger being remov'd from the Top, the Oyl in the ſhorter Leg, will be immediately driven down (according to our noble Author's Experiment) about an Inch, and as the Tube ſinks lower, much more, till at laſt the Oyl ſhall be driven out of that Leg quite, and the Water following ſhall ſupport the Oyl in the longer Leg, raiſing it alſo in the ſame Proportion; the Reaſon of which is plain from what has been ſaid before.

Our noble and ingenious Author found alſo that when he us'd the Siphon hereunto annex'd (as *vid. Fig.* 16. *Tabula ſeq.*) that the Water would firſt preſs the Oyl horizontally from L, to M, then downwards from M, to N, and at laſt (by ſinking the Tube ſtill lower) upwards from N, to P; from whence it follows, that Water preſſes againſt any Body plac'd in it all Manner of Ways, and that proportionably to the Depth of the Body in it.

PRO-

PROPOSITION IX.

That notwithſtanding whatſoever has been ſaid of poſitive Levity, a Parcel of Oyl lighter than Water, may be ſo detain'd in Water that it can't aſcend in it.

THAT I may ſhew the more clearly (ſays our noble Author) thoſe things which I have to ſay concerning this Paradox or Propoſition, and to produce thoſe Conſiderations which are neceſſary to explain what is here aſſerted; this Propoſition is ſet down.

AND in this Caſe it will be uſeful to conſider how it comes to paſs, that any Body that is ſpecifically lighter than Water, and which is collected together in the Bottom, below the Superficies of the Liquor, ſhould rather emerge or riſe to the Top, than deſcend to the Bottom of it, unleſs we ſhould make uſe of the aforegoing Problem in the Explication of the third Paradox; but becauſe it is more proper to apply to our preſent Purpoſe, what is there deliver'd, I ſhall immediately ſubjoin the Reaſon (tho' it does not ſeem poſſible) why any Part or Portion of Oyl, tho' it be lighter than Water, ſhould be detain'd againſt its own Inclination, that it ſhould not emerge to the Top; which is becauſe the Superficies of the Veſſel being (phyſically ſpeaking) full of ſtagnate Water, the horizontal Water, which preſſes the inferior Part of the immers'd Body, muſt be neceſſarily deeper than that which preſſes the ſuperior.

THAT this may be reduc'd to Practice let the following Method be us'd, take only a ſmall glaſs Tube, and immerge it an Inch or two under Water; ſtop the Orifice with the Pulp of your Finger, and then a Column of Water, of an Inch or two in Length, will remain ſuſpended in the Tube; keep it ſo, and next of all dip the ſame Tube into a Veſſel of Oyl of Turpentine, and removing your Finger, as much Oyl of Turpentine, as you pleaſe will ariſe into the Tube; which by putting on your Finger to the upper Orifice may be there ſuſpended, as the Water was before; keep it ſo, and then immerge the Tube in a Glaſs of Water three or four Inches beneath its Surface, and you will find on the Removal of your Finger, that the Water will riſe up into the Tube, and keep the Parcel of Oyl ſuſpended between two little Columns of Water.

THE Reaſon of which has already been ſet down in many Inſtances, but may be more plainly diſcover'd in the annex'd Table *Fig.*

17.

7. where P, Q, is the Water lately put into the Glaſs; Q, R, is Oyl, and R, S, Water, which was firſt of all ſuck'd into the Tube; for in this Station all theſe three Liquors altogether and equally gravitate upon the Part P, and the incumbent Water only on the other Parts of the imaginary Surface G, H: Neither does the Oyl R, Q, aſcend, becauſe when the ſpreading of the Water R, S, is ſtopt by the Sides of the Tube. A, D, is higher than the reſt of the Water; by which Means the incumbent Water is brought thither, ſo that the ſuperiour Oyly Part R, of the Cylinder aforeſaid, preſſes equally, and the Water endeavours again to impel the lower Part of the ſame Cylinder of Oyl Q.

PROPOSITION X.

That the Cauſe of the Aſcenſion of Water in Siphons, and its Tranſition thro' them is explicable, without having Recourſe to Nature's Abhorrence of a Vacuum.

When many Philoſophers and Mathematicians amongſt the Ancients, who were not well acquainted with this Propoſition, had any Difficulty to reſolve, they had an immediate Recourſe to the *Fugæ Vacui*, that ſo they might explain the Cauſe of the Tranſition of Liquors thro' Siphons; and thoſe Moderns alſo, which admit of a limited Vacuum (which to me ſeems certain, as our learned and noble Author has it, *Pag.* 141. of the *Latin* Edition,) they have left the Phænomenon unexplain'd, or have endeavour'd to explain it by litigious Notions, ſo that the Curious are (as he believes) much indebted to the moſt learned *Paſchal*, who has ingeniouſly undertook to ſolve the ſame.

This Problem is not really ſo difficult, as that we muſt have Recourſe to the *Fuga Vacui* ſo much heretofore talk'd off, for that in Truth the Explication of the Motion of Water in Siphons, Syringes, and Pumps, ſeems very conſonant to the Principles of Hydroſtaticks.

To proceed to Experience, provide a pretty large cylindrical Glaſs Tube, of about 18 Inches or two Foot long, as A, B, C, D, *(Vide Fig.* 18. *Tub. Seq.)* provide alſo a Siphon of two Legs, K F, K G; provide alſo a Siphon K F, K G, with a hollow Pipe, as K E, opening into or communicating with them, to each of theſe two Legs of the Siphon (one of which muſt be longer than the other) tye with a String a Tube of Glaſs I, H, ſeal'd at the Bottom, pour therein Water at E, and let it run out at I, and H, till

till it hath fill'd the Tubes hanging at the Ends of the Legs of the Siphon ſo far, that the End of each Leg be a little beneath the Surface of the Water.

THIS being done, and the Inſtrument and Pipe faſtned in its true erect Poſition, if you fill the Veſſel A, B, C, D, with Oyl of Turpentine, till it reach higher than the Siphon K, ſtopping in the mean Time the upper Orifice of the Pipe E K, with your Finger, you will find the Oyl to preſs ſo on the Water in the Tubes I and H, as to force it up into the Legs of the Siphon ſo high as K; and that in the removing of your Finger from the Top E, the Water will begin to run out of the upper Tube I, into the lower one H, as in or thro' a common Crane or Siphon.

NOW it is apparent as Light it ſelf, in this ſo well contriv'd an Experiment, that the Water runs thro' the Legs of the Siphon, tho' the Air coming down by E K, hath a free Communication with them both: So that here no *Fuga Vacui* can be pretended, as the Cauſe of the Waters running; but that 'tis plainly occaſion'd by the Preſſure of the lighter Fluid, *viz.* the Oyl of Turpentine on the Surface of the Water in the Tube I, till it force it up into the empty Leg of the inſerted Siphon as high as K, and then it deſcends down into the lower Veſſel of Tube H, thro' the larger Leg of the Siphon.

THE Oyl indeed will gravitate on the Surface of the Water in both the Tubes I and H, and there being a longer Column of Oyl over H, than there is over I, by about an Inch in Length, the Preſſure will be greater on the Surface of the Water in H, by the Weight of an Inch of Oyl of Turpentine; but then it muſt be conſider'd, that the Column of Water which deſcends in the Leg G, though reſiſted in its Motion by the Weight of an Inch of Oyl, more than the Water which tends downwards in the Leg F, is yet longer by an Inch, than the other Column of Water in the ſhorter Leg F, and an Inch of Water of the ſame Dimenſions, being heavier than an Inch of Oyl, the Tendency or Motion of the Water muſt be from F, towards G; and not from G, towards F; and conſequently the Crane or Siphon will work that Way.

" FROM hence, (ſays an induſtrious Author, Dr. *Harris)* 'tis plain " that when once a Crane or Siphon by Suction or otherwiſe, is " fill'd with the Liquor it is to decant; if the Legs of it be not " above 33 or 34 Foot long, one of them being longer than an- " other, the Liquor muſt continue to run thro' it as long as there " is any to riſe in it, or that the Siphon hold ſtanch; but then, " if never ſo little a Hole be made in the Crane or Siphon, or " any

" any Leak be there, the Water can no longer run, becauſe the " Air now comes to preſs on the Water within the Siphon, as " well as on that without it, and conſequently muſt hinder its " Courſe of Running."

THE ſame will, (with that induſtrious Gentleman's Leave) happen in any common Crane or Pump, where the Air will (by its Elaſticity) be continually intruding itſelf in, at the leaſt Intermiſſion of the Water's running; except there is a Syringe continually at work to draw off all ſuch intruding Air, which will ſtill be endeavouring to deſtroy the Ballance in the Ingreſs of the Water into and Progreſs through the Pipe, as it is ſeen in decanting Wine and other Liquors where the Crane is not above a Foot high; and if it happens to be ſo in ſmall Caſes, what may we not expect when we are to raiſe and decant Water 32, 33, or 34, or more? But of this more hereafter.

PROPOSITION XI.

That a ſolid Body as ponderous as any known, tho' in the Surface of the Water, will ſink by its own Weight; yet if it is plac'd in a greater Depth than that of its own Thickneſs, it will not ſink, if its Deſcent be not aſſiſted by the Weight of the incumbent Water.

OUR learned and noble Author is very ſure this Paradox or Propoſition was never before propos'd by any Body, and therefore it was not likely to appear true to thoſe to whom he had produc'd it (the Mathematicians themſelves not excepted); and that he could ſcarce hope that that illuſtrious Society, of which he was a Member, ſhould readily and univerſally agree to it, unleſs induc'd thereto by Experience.

THAT we who are his Followers may proceed therefore in a regular Method, he has directed to fill a glaſs Veſſel of about two or three Foot in Length (with a large Tube ſeal'd at the End) with Water as is ſeen (*Fig.* 19. *Tab. ſeq.*) If then a little Cylinder or Cube of ſolid Braſs, as E, be any where plac'd, either at the Surface, in the Middle, or towards the Bottom of the Veſſel, ſtill it muſt ſink to the Bottom; becauſe the compound Column of Water and Braſs together (Braſs being almoſt nine Times as heavy as common Water is) will gravitate or preſs more than any Column of Water only, of the ſame Length and Diameter; and conſequently the Braſs will diſplace the Water under it, and ſink lower and lower

 till

till it comes to the Bottom, and this is the Cafe of a Stone or any other heavy Body; but yet if you fuppofe this Piece of Brafs plac'd on the imaginary Surface L, M, above nine Times its Depth under Water, and that it were poffible to keep off the Preffure of the Water perpendicularly incumbent upon it; it is not reafonable to fuppofe that the Brafs would fink at all, but be fupported and buoy'd up there; for the Brafs can in this Cafe charge the Water under it at F, with no more than juft its own proper and abfolute Weight; whereas all the other Parts of the Surface L, M, are charg'd or prefs'd upon by Columns of Water, which fuppofing them to be of the fame Diameter with the Piece of Brafs, (or fingly heavier than the Brafs, becaufe they are above nine Times as long as the Brafs is thick) and are therefore preffing or gravitating more on L, M, than the Brafs doth, muft of Courfe keep the Brafs fufpended which cannot fink, becaufe it can't remove a Weight of Water heavier than it felf: And from the fame Principles 'tis plain from Reafon, that if the Brafs be plac'd yet lower, and the Preffure of the incumbent Water be (as before) taken off, inftead of finking it muft needs rife, and be lifted up by Force; and this is the Reafon that Bodies of different Gravities fwim either higher or lower if gently immerg'd in Water according to their Thicknefs and fpecifick Gravities: And this alfo muft be the Cafe of a Piece of Gold (the heavieft of all Metals) if it were plac'd in thefe Circumftances, in a Veffel full of Water where the perpendicularly incumbent Preffure was kept off, and the Gold nineteen Times its own Thicknefs in the Liquor.

From hence I fay, (fays our noble Author) if any Body or Piece of Brafs be plac'd deep enough below the Surface of the Water, and fo defended that no incumbent Water can prefs it; it will be fuftain'd by the fubjacent Water, and this is what fhall be made out farther in the following Experiment.

Let there be a Piece or Body of Brafs E, F, having a Cover or brafs Valve well cemented, in which let there be well turn'd and fitted a Piece of folid Brafs as E, F, abovemention'd; let a deep glafs Veffel be provided in the Shape of *Fig.* 20, in the following Plate, which Veffel let be fill'd with Water near to the Top, then at the Bottom thereof let there be a glafs Tube open at both Ends, into which the brafs Valve abovemention'd was faftned, which tho' it would ftop the Valve exactly, would yet eafily fall out, if not fufpended or fupported by any thing: To the upper Side of the brafs Piece E, F, let there be a Button faftned, whereby it may

may (by Means of a String coming up through the Pipe P, O,) be drawn cloſe up, ſo as to ſtop the Valve.

All things being thus fitted, if you ſink the Tube with its Valve and braſs Stopple faſt in, till the Braſs be about nine Times its Thickneſs beneath the Surface of the Water in the glaſs Veſſel? You will find tho' you looſen the String, that the braſs Stopple will not fall out; becauſe the Valve being cloſe, and the Sides of the glaſs Tube not capable of being permeated by the Water, there can no more of that Liquor preſs upon the braſs Stopple perpendicularly; but whatever Preſſure it ſuſtains is from the Tendency of the Water upwards, which muſt needs ſerve to ſupport it, ſince that is greater than the Weight of the Braſs. But if you raiſe the Tube up towards the Top of the Water, the braſs Weight there over-ballancing the Preſſure of the Water upwards, it will ſoon; if not held by the String, ſlip out of the Valve and fall down, and the Water will immediately riſe in the Tube.

But if inſtead of raiſing the Tube up towards the Surface of the Water X, Y, you would ſink it down much deeper towards the Bottom; you will find that this braſs Stopple which will fall out readily into the former Station, will now ſupport a conſiderable Weight (as L,) faſtned to it by a Bottom made on the under Surface of it; but that on the raiſing of the Tube upwards, this additional Weight will make the Stopple drop out much ſooner than before: As ſuppoſe when the Tube is rais'd only to the Height of three or four Inches &c. which Experiment does abundantly confirm the Truth of this Paradox or Propoſition; and no doubt had the Stopple been made of any other Metal or Material more ponderous than Braſs (ſuppoſe Gold) and that the Tube had been let down into the Veſſel, till that Gold or other Metal had been nineteen Times its Thickneſs (or what Thickneſs ſoever elſe its ſpecifick Gravity requir'd) even that ponderous Metal (let it have been what it would) would have there remain'd without ſinking.

From whence (at one View) may be ſeen that which happens when two plain and poliſh'd Pieces of Marble are join'd together, where we ſhall find it impoſſible to ſeparate them without great Strength; neither is there Occaſion to have recourſe to the *Fuga Vacui* for the Explanation of Cohæſion; for whilſt thoſe Pieces are encompaſs'd with the ambient Air, which is a Fluid not deſtitute of Gravity, and ſtretch'd out I know not to how great a Height above the Marbles, they can't poſſibly ſeparate; for then it muſt needs keep the Stone pendulous or buoy'd up, till ſuch Time as the Air inſinuates itſelf between the Stones, or that a

 Weight

Weight be affix'd to the lower Stone which exceeds the Weight of a Pillar of Air, whoſe Diameter is that of the Marble, and its Height reaching to the Top of the Atmoſphere: And that this is the Reaſon of their Cohæſion is plain, becauſe when they are thus ſuſpended, and do adhere to each other in the Receiver of the Air-pump, on a very few Pumpings of the Air out of the Receiver they will immediately disjoin and fall aſunder, as ſeveral learned Men have experienc'd; and it may be prov'd that there is nothing elſe but this Preſſure of Water which I have juſt now explain'd, which cauſes this Cohæſion of the Parts of the Valve; for if it be elevated by Degrees towards the Superficies of the Water, you will ſoon find the Piece of Braſs E, F, to be drawn downwards from the Stone, which will hang to it, juſt as you perceive of Water creeping between the Parts of the Valve and aſcending in the Tube.

To all which I only add, what will hereafter be made more plain, that conſormable to our Doctrine, when the Preſſure of the Body E, F, upon the ſubjacent Water, is a good deal encreas'd by the Weight of the Stone which is hanging to it; there is no Occaſion of a Valve as before, to elevate it above the Plan I, K; for the overcoming the Reſiſtance of the Water, when it is ſo built as to be capable of performing that by its own Force, before it can be elevated to its proper Height, which is all I ſhall in this Chapter add from this illuſtrious Author.

BOOK.

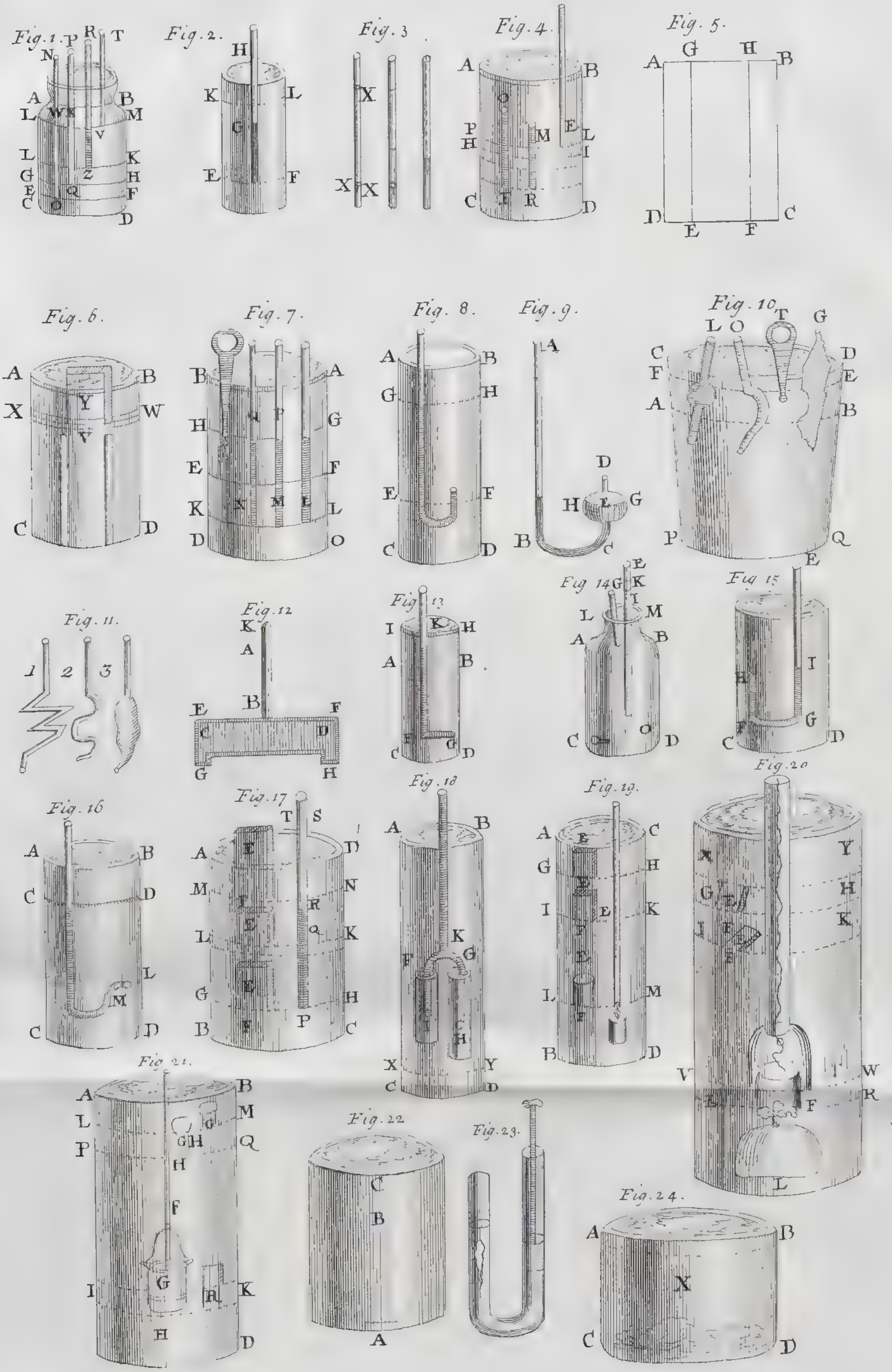


Fig. 1.
Fig. 2.
Fig. 3
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10
Fig. 11.
Fig. 12
Fig. 13
Fig. 14
Fig. 15
Fig. 16
Fig. 17
Fig. 18
Fig. 19.
Fig. 20
Fig. 21.
Fig. 22
Fig. 23.
Fig. 24.

BOOK. II.

CHAP. XIII.

Of the ſo much diſputed Vacuum *of the Ancients, and of the natural Effects of Air and other Fluids in Hydroſtaticks.*

THAT I may explain what is meant by the *Vacuum* and *Plenum*, of which mention has been made in the foregoing Chapters, and which was for ſo many Ages the Diſpute of a great many great Men; it is requiſite I ſhould trace and diſtinguiſh, with as great a Perſpicuity and Plainneſs as I can, what the Advocates on either Side have advanc'd in Favour of their beloved Hypotheſis; ſome whereof maintain'd an abſolute *Plenum*, and the other as ſtiffly an abſolute *Vacuum*, *Inane*, or empty Space; wherein otherwiſe they tell us *we can't move, for that one Subſtance can't move in another.*

I was once indeed in the Mind not to have gone ſo far back, as to have meddled with an Hypotheſis which has been ſo long controverted, and till of late ſo little determin'd as this is; but then I thought I ſhould not do Juſtice to my Subject, nor ſet this Affair into its true and genuine Light, without examining the moſt material of the Arguments *pro* and *con*, on which the Practice of Hydroſtaticks and Hydraulicks are founded; being willing that thoſe which muſt be obliged to tread theſe Paths, and to endeavour to get their Knowledge by Application and Books, as I have done, may have their Journey made as plain and eaſy as poſſibly it can be.

AMONGST the ſeveral Repreſentations which many Sages of Antiquity have made uſe of, to aſſert the Improbability of a *Vacuum*, (which tho' ſtiffly maintain'd by ſome, was as reſolutely deny'd

ny'd by others) was that remarkable Poſition for which *Ariſtotle* himſelf was the greateſt Champion, *Quod Jovis omnia plena:* In which it was imply'd that all Hollows or ſuppoſed Vacuities were full of Air or ſome other Subſtance, (which ſtill maintain'd the Doctrine of a *Plenum*) which Air was of ſuch a Nature as to recede and give Place to whatever came into its Way, and then return again to its firſt Scituation and Poſition, and that there was really no ſuch thing as a *Vacuum* or empty Space in the whole Compaſs of Nature, which they demonſtrated, or at leaſt endeavour'd to demonſtrate, by undeniable Arguments; and that it plainly appear'd by the bare Inſpection of the Outſide of a glaſs Veſſel fill'd with Air, which being compreſs'd on every Side by the pouring in of Water produc'd ſo many extraordinary Effects; and this they produce as the Foundation on which ſo many uſeful Arguments are brought to light; for the better and clearer Demonſtration of all that can be ſaid concerning the Motion of Water by Engines or otherwiſe.

Many there are (ſays the laborious *Bockler*, Lib. 1. Pag. 4.) of no ſmall Note, which have endeavour'd to demonſtrate that there is a *Vacuum* or Place empty and devoid of all Matter, from an Argument drawn from Quickſilver's being poured into a glaſs Tube, where it dilates or contracts itſelf, or, according to common Obſervation, riſes and falls, as the exterior Air is more or leſs ſubtle or denſe: But as the ſame Author obſerves, whenever they go about to do it by this or any other Argument, they appear to uſe thoſe that are artificial or mechanical, rather than thoſe that are natural, and therefore of little or no Uſe at all.

Democritus and *Leucippus* (as we have it from the ſame *Bockler*) being of the firſt Rank of the *Pythagorean* Philoſophers, did ſuppoſe that there was nothing elſe but a *Vacuum*, or empty Space, which ſeparated and divided ordinary things, and which was this large Vacuity in which we live; and then affirm'd that the World was a large Animal, from whence this Vapour-ſpirit or Air extended itſelf *ad Infinitum*, which they ſay was a clear Demonſtration of this *Vacuum*, and ſuppos'd that this Action was firſt perform'd by the voluntary Aſpiration or Breathing of this Globe, and *e' contra* draws in again by its Reſpiration.

Anaxagoras (by Name) another Philoſopher of great Account, ſuppos'd alſo that there was a large *Vacuum* in the Place where we ſuppoſe the Air to be inviſible to human Sight, and demonſtrates that there was nothing in Nature more real and plain; by an

an Example of a Bladder's being blown up and extended in ſuch a Manner, that it could not without great Difficulty be compreſs'd again.

AND the ſame laborious Philoſopher endeavours to illuſtrate this his Opinion by another Example of a Watering-ſiphon. This Inſtrument ſays he, which is acuminated or pointed towards the Top, and made of Clay or any other Material, and uſed, as it often has, for the watering of Gardens, is in the Bottom very large and plain, but full of ſmall Holes like a Sieve; but at the Top the Orifice is only one large Hole.

THIS Veſſel, by the Intruſion of Water or Vapour paſſing through the open Spaces of the Bottom, is eaſily fill'd therewith, which otherwiſe it would not be, were it not for the large Orifice that is at Top by which the Air paſſes and is excluded, being reſiſted or ſtopt out by the ſuperior Subſtance, Body or Force of Water paſſing in or through it: And in like Manner a Veſſel full of Water, if it be ſhut or cover'd over at Top, and for that Reaſon the Entrance of Air is deny'd the Water that is poured in, nor any thing elſe will flow out below; becauſe, according to *Anaxagoras*, nothing but Air, a Subſtance nevertheleſs inviſible, can thus paſs.

BESIDES theſe Philoſophers, *Meliſſus* alſo upon the Foot of his own Experience proceeds to demonſtrate a Vacuity from the following Reaſons; all things (ſays he) that are moved or encreas'd, are moved and encreas'd in a certain or determinate Place, ; that this Place is either a *Plenum* or a *Vacuum*; if it be a *Plenum*, there will be two, three, or four, or perhaps an Infinity of Bodies in the ſame Place, the greater muſt be contain'd in the leſſer, the equal and unequal in the ſame Place, which are amongſt the Contrarieties and Impoſſibilities of Nature.

FROM whence he argues, that all Motion and Augmentation happens in this Vacuity, and that ſuch a thing is neceſſarily imply'd in the very Nature of things; for the moving of all Bodies therein, on which alſo (in the Opinion of this Philoſopher) is eſtabliſh'd the Certainty of the Moveableneſs or Rotation of the World, and to ſuppoſe that this univerſal Motion could be effected any where but in a *Vacuum*, would be abſurd.

FROM hence he infers, that it is as plain as Light itſelf, that every *Plenum* or corporeal Subſtance neceſſarily has its Being in the Place of another apparent Body, which, ſays he, is in Truth no other thing but that memorable *Vacuum* by him as well as others ſo much contended for.

HAVING thus given a ſhort Account of the Opinions of *Democritus*,

mocritus, *Leucippus* and others, who have been endeavouring to eſtabliſh the Doctrine of a *Vacuum*; *Ariſtotle* deſcends the Stage arm'd with four different Arguments, which nevertheleſs (for Brevity Sake) *Lampſacenus* contracts into two; one that relates to the Motion, and the other to the Conſtriction or Condenſation of Bodies.

In the firſt Place (he ſays) that he can't follow that Maxim, which implies that Motion being once allow'd, a *Vacuum* alſo muſt follow of Courſe; for altho' it is certain that nothing can move in a *Plenum*, yet the Methods are to be obſerv'd whereby Bodies give Place to one another, and relinquiſh Space to Motion, or in other Words interchange the one for the other.

So it is that a Stone which is thrown up into the Air is ſaid to be mov'd, not as tho' it was in or through a *Vacuum* or void Space, but ſo as that the Air is lighter and more penetrable than other Bodies are, and ſo gives Place to a greater Force, and then after that returns to its former Poſition, even as the Sea gives Way to a loaded Ship, which, tho' it plows the Water and ſeems to leave a Furrow behind it, ſoon fills up again and returns to its former Level.

As to what relates to the other Argument, it is very weakly inferr'd from the Compreſſion of Bodies that there is a *Vacuum* mixt with them, which ſuffers Bodies of a thinner Subſtance to be ſo conſtricted; for ſays that learned and intelligible Author, every thing which is condens'd is contracted or compreſs'd one within another, as it contains a Body of a more ſubtle Nature, which being compreſs'd in the aforeſaid Manner paſſes through the ſame Pores or Perforations in which it was before found, giving Place to the Contraction and Condenſation of larger and heavier Bodies, as we ſee Air evaporates and diffuſes itſelf when compreſs'd by the more powerful Body of Water, the Weight of Water to that of Air by ſeveral later Experiments being found to be between 8 and 900 to 1; as Dr. *Deſaguliers* and others have ſet down.

That which they urge from the Dilatation, Augmentation, and Rarefaction of Bodies, and that would infer from thence (as the learned and laborious *Bockler* has it) that the *Vacuum* reſides amongſt thoſe Principles, argue (contrary to what later and better Philoſophy teaches) what is very abſurd and without any real Sound or Signification; for indeed this Kind of Augmentation happens by the Accretion of ſome other new Magnitude on the former, or that I may ſpeak more intelligibly, by the Revolution, Union, or Joining (call it which you will) of a thicker Subſtance on

on that which is thinner; even as Air, which (as he ſays) is generated by Water, is by far more extenſive and fuller of priſtine Humor: Although no new Subſtance ſhall have any Acceſſion or Addition to it, for which he refers to *Cornel. Drebblinu*'s *Tracts of the four Elements;* and alſo *Benj. Bran. de Vacuo.*

The Argument that is fetch'd from Aſhes, turns it ſelf againſt its own Authors, (ſays this laborious Philoſopher) for whilſt Aſhes receive and ſup up Water; they intromit it, either into a *Plenum* or a *Vacuum;* into a *Plenum* they can't, becauſe, according to their own Opinions, one Body cannot penetrate into another; it therefore follows, that it muſt be received and admitted into a *Vacuum.*

But if we ſhould by Way of Conceſſion, and to pleaſe thoſe Gentlemen, allow an abſolute *Vacuum,* it would infer no more than that that *Vacuum* (which is really nothing at all) encreaſes and decreaſes, is dilated and contracted, which is an Abſurdity; for upon ſuch a Suppoſition, that this *Vacuum* could extend and contract it ſelf like a Subſtance or Body, it would thence follow, that it was one and the ſame Thing that a Body was; and therefore nothing different from a *Plenum,* by which Means they deſtroy the Doctrine of a *Vacuum,* when they go about to eſtabliſh it.

And that the Argument concerning Aſhes, (which the Advocates for a *Vacuum* make uſe of) is making rather againſt, than for them; *Eridemus* in his third Book *De Cauſis Naturalibus,* thus ſolves, ſtating the Caſe thus, That tho' Water be poured on Aſhes, it does not follow, that that Water can be received, or, as it were, abſorb'd and lick'd up thereby; for if there ſhould be any vacuate Pores or Angles which imbibe the Water in ſuch a Veſſel, yet in Aſhes, or, which is much to the ſame Purpoſe, ſlack'd Lime there is always a certain inward Heat, labouring as it were in its own Bowels which, when it meets with Moiſture, cauſes it to change as quick as Thought it ſelf, and evaporate into Air, which appears plainly to the Eye, by the Aſcenſion of the Smoak and Vapour.

Another Reaſon made uſe of by the Advocates for a *Vacuum, Ariſtotle* himſelf ſolves in his Problems; and in this Manner he asks why Wine, that is beforehand ſufficient for the filling of a Hogſhead, but being poured out of it into glaſs Veſſels, can't fill the ſame again, but leaves Room for pouring in more at Top. This Queſtion (I ſay) this great Philoſopher anſwers himſelf, by ſaying, That Wine contains in it ſelf a certain Quantity of Spirit or Air, which the Thickneſs and Largeneſs of

 the

the Veſſel does not ſo eaſily give Leave to evaporate or let go, as Glaſſes do; out of which being poured, by little and little, that which is poured off loſes its aerial Spirit, and gives Room and Space for the pouring in of more Wine to fill it up: And I add, that when this Spirit or Air is evaporated, that then it is that Wine and other Liquor grows dead and flat, the aerial Spirit being evaporated and gone, that contributes ſo much to its Briskneſs.

To proceed with this laborious Philoſopher, it is evident, that Air and Water ſeparate themſelves with more Difficulty from a large Body than it does from a ſmall one; as a large Spunge that is fill'd with Moiſture, cannot be freed from it by ſqueezing ſo exactly, or with the ſame Eaſe and Diſpatch, as it will from a Spunge of a leſs Amplitude; and certain it is (ſays he) that Wine contains more Air than Water does: And it may be added from Experience, that the more generous Liquor is, the lighter it is; containing more Spirit as before; which alſo, ſays our oft-quoted Author, agrees with the Experiment concerning Aſhes; to wit, that whilſt the ſame Quantity of Water and Aſhes are put at one and the ſame Time, into one and the ſame Veſſel; it takes up the ſame Room, and no more than it did before, ſeparately and ſucceſſively (which; ſays our ingenious Author, is very eaſy to underſtand) for Aſhes, being a very light Subſtance, contains in its own Pores and Receſſes a great Quantity of Air; upon which Water being poured, which is more ſubtile and thinner than the terrene Subſtance of Aſhes, inſinuates it ſelf thereinto, and by Degrees contracts more Strength (becauſe every Thing which is compreſs'd, ſenſibly and by Degrees, and not by one Force only, is heavier and of greater Denſity in its own Nature, than that which is lighter.) By which Means Aſhes naturally condenſe Water, whilſt it is abſorbing or drinking it up; and at the ſame Time evaporates a great Deal by Steam into Air, (if they are hot) that they may make Room for what remains.

But to draw as ſoon as poſſible towards a Concluſion of theſe Opinions of the Ancients, which are ſomething hard to underſtand; there were many more (ſays *Bockler*, Lib. I. p. 7.) amongſt thoſe Sages of Antiquity, and ſuch as were well skill'd in Philoſophy, even as many as liv'd from the Time of *Thales* the *Mileſian*, to *Plato*, that abſolutely deny'd that there was ſuch a Thing as a *Vacuum* in the Univerſe, from whence came that famous Verſe of *Empedocles* of *Agrigentum*.

2 *Nil*

Nil Vacuum in toto eſt plano, aut circumfluit Orbe.

Yet altho' *Ariſtotle*, that Prince of Philoſophers, appear'd to have baniſh'd the Notion of a *Vacuum* out of the World; yet *Plutarch* writes, that he held there ſhould be as much Æther as Fire, for the ſake of Breathing: However, as there are no Footſteps found in any of *Ariſtotle*'s Writings, that tended thereto, but on the contrary, (and in Oppoſition to the *Pythagoreans*;) he is every where found ſtemming that Opinion of theirs, with all the Might he could, it may be infer'd that he held no ſuch Thing.

Macedonus Epicionus, a Philoſopher of *Etruria*, was of another Opinion, and ſays, That this *Vacuum* was placed without or near the Confines of the World, telling us that there are a Multiplicity of Atoms fluctuating and confuſedly extending themſelves under this *Vacuum* or empty Space, into which *Vacuum* upon any Occaſion, (as may be inferr'd from his Writing,) thoſe lower Particles of Matter intrude themſelves, when agitated or diſturb'd by any potent Body.

To give this Hypotheſis its due Emphaſis and Weight, he ſays, That God Almighty is the Giver and Upholder of all Things, within this habitable World; but that which is without or above it, is the Seat and Habitation of that glorious Being, without any Limit or Subſtance, corporeal or immaterial, of eternal Duration; and this (with how great a Probability of Truth I know not) he terms a *Vacuum*; from whence he has infer'd, that this *Vacuum* or empty Space is not admitted within the Confines of this aerial World, for there being known Bodies of a like Nature, full of all that is proper to their reſpective Beings, and compos'd out of heavenly and cœleſtial Elements, can't after that admit of any Thing, contrary to the Nature of what he had before ſet down.

Of this Opinion alſo was *Cleomedes*, a noted Philoſopher of Antiquity; againſt all which *Ariſtotle* deſcends the Stage again; but as the Squabble is long, and the Arguments on each Side are manag'd in a kind of a confus'd Manner, rather than that which is Mathematical and ſelf-evident, I ſhall not trouble my Reader with it. But ſhall only, to what I have ſaid on this Head, add from later Times, the Opinion of *Hero Alexandrinus*, a noted Writer in Hydroſtaticks, who ſays, That there were in his Time a great many amongſt the Learned, that deny'd any Kind of *Vacuum* in the World: But for my Part, ſays he, I do agree and eſtabliſh it as my Opi-

nion, that there is fuch a Thing, but that it is not gathered together in one Place, but minutely and by infenfible Particles, or fmall Parts, diffeminated and difpers'd this Way and that Way, thro' Water, Air, Fire, and all other Bodies.

For altho' a Diamond, which, becaufe of its natural Hardnefs, cannot be penetrated either by Fire or Steel, (certainly from the Reafon and Proportion of it) yet it does not follow, that this Diamond is deftitute of all Vacuity, but that it maintains its conftant and impenetrable Hardnefs, from a thick invifible Subftance.

For the fuller Demonftration of this Pofition, it is to be obferved, that Air is a Body compos'd of minute, very light and inconfpicuous Particles or Atoms, which mutually, firmly and in all Places cohere to one another, but yet leaves fome fmall vacant Spaces within it felf, in like Manner as Sand is gathered and heaped up together on the Sea-fhore. Suppofe then thefe Arenula's, or fmall Grains of Sand, to be Atoms or Particles of Air, you will perceive a foft gentle Wind or airy Subftance in the Place of the aforefaid *Vacuum;* from whence it often happens, that by the preternatural Compreffion of thofe two Bodies, the included Air is of Courfe condens'd, and oblig'd to refide in thofe Vacuities or empty Spaces; but as foon as this compreffive Power is remitted or relaxed, it immediately returns from what it was to its firft State and Magnitude, as is feen in bended Horns and dry comprefs'd Sponges (the Power or Force being over, whereby they were comprefs'd) which, according to their own natural Affection, return to their former State and Place.

Almost the fame Effect follows, where Particles of Air are emitted or chas'd away out of any Place or Veffel, by any extraordinary Violence, for that they quickly flow together again, from an innate Affection that is in their Nature one to another, and left the *Vacuum* fhould extend it felf beyond its juft Bounds; for this Motion, or rather Flight of the Particles of Air, accelerates (if nothing elfe hinders) this very *Vacuum.* For we find by every Day's Experience, that if any light Veffel having a narrow Orifice or Mouth that moves, it attracts the Air with it in a very ftrong Degree, and if you apply your Lips to it (left the *Vacuum* fhould have too much Space) it will adhere to them, contrary to its own Nature, that the fuppos'd *Vacuum* may be compleated and fill'd the better; and the fame Thing happens in a Syringe, which is us'd in fprinkling or difperfing of Water or Moifture over any Thing; as alfo in all Cucurbits or Cupping-Glaffes,

Glaſſes, us'd in common Scarifications, as is eaſily demonſtrable to the Eye.

And that this may be the better underſtood, (our Author argues) that the Cover of a Braſs Veſſel being made very ſtrong and hollow, or of a ſpherical Figure within, and which will hold one and a half, or two Meaſures of any Thing, and let it be every Way well ſhut and conglutinated or ſealed together; make a Perforation or Hole, on the Top of this ſpherical Veſſel, and put down therein a Tube perpendicularly; but ſo, as that it may not touch the Bottom, but have a neceſſary Space for the Water to fluctuate: Let this little Tube be carried higher than the Veſſel, and the Bung-hole of the Veſſel exactly ſtop'd three or four Fingers thick, or more, as it is done in all other Caſes of this Kind: If therefore, according to the Opinion of ſome, there is no *Vacuum* within this Sphere; it conſequently follows, that there is neither Air nor Water in it, and that it is a *Plenum.*

But this is not ſo, for if the aforeſaid Tube be mov'd to your Mouth, and you adjoin it thereto, and blow with what Strength you can, all, or a great Part of the Air that was before encloſed in the Veſſel, will paſs, and hurry out with great violence: From whence it muſt be infer'd, that there is a Kind of *Vacuum*, or empty Space, wherein that Air was included; which, as was ſaid before, was condenſed and contracted, and might admit of more; or if you would have it otherwiſe expreſs'd, when you have ſuck'd out one Part of the Air, in the Room of which no other can be admitted, it is neceſſarily and conſequentially imply'd, that there does remain a certain *Vacuum*, though not ſuch as has been often underſtood within this ſpherical Veſſel; but ſo, that it may be eaſily encreas'd or extended by Reſuction. From all which it is evident, that there are vacuated and diſpers'd Spaces in the Air, by the Intervention of which, it may be condens'd, rarify'd, or expanded: All which tends to what our more modern Philoſophers ſet down on this Head, who have diſtinguiſh'd it into a *Vacuum diſſeminatum ſive interſperſum*, &c. Having thus trac'd the Opinions of the moſt knowing amongſt the Ancients, let us now have Recourſe to what our more modern Philoſophers have argued on this Head.

Rohault, one of the chief amongſt the *Carteſian* Philoſophers, (for I have not had the Opportunity of examining what *Deſcartes* himſelf has advanc'd, (Part. I. Cap. 8.) as we have it from that excellent Verſion of Dr. *Clark*'s) affirms, that there can be no ſuch Thing,

Thing, as what the Philoſophers call an *inane* (*) or empty Space, ſince by that *inane* they underſtand a Space without any material Body in it; but to us, (ſays he) Space and Extenſion is one and the ſame Thing; and that to enquire whether Space can be without Matter, is to enquire whether Matter can be *ſine materiâ*.

But that excellent Divine, who by his great Learning has been ſuch an Honour to his Country in general, as well as a great Benefactor to Philoſophy in particular, poſitively affirms from the Nature of Gravity, that there is ſuch a Thing as a *Vacuum*, and which is greatly viſible in all ſublunary Beings. And, upon the Foot of the *Newtonian* Principles, proceeds to demonſtrate it from the Motion of Comets: For when Comets, ſays he, are by any long continued Motion carried every Way, and in all Parts through the celeſtial Spaces above, (they neceſſarily cut the Orbs of all thoſe Planets they meet with croſs-wiſe) from whence it is evident, that thoſe celeſtial Spaces are free from all ſenſible Reſiſtance, and conſequently free from all ſenſible Matter, and which alſo (I may add) neceſſarily implies a *Vacuum*.

The ſame Thing holds good of pendulous Bodies, for that Bodies of this Kind meet with no Reſiſtance, where the Air is not exhauſted; from whence it is plain, that there is no ſenſible Matter in thoſe Spaces, or in the occult and hidden Meanders of thoſe Bodies: The *Carteſian* Suppoſition, that the Thinneſs of any ſubtle Material, (ſuppoſe Air) may be the Cauſe why its Reſiſtance is not ſenſible; and that a ſmall Body running upon, or meeting one which is greater, can't move it at all, or any Way hinder its Motion, but that it will reflect back with all the Expedition imaginable, is fooliſh, and contrary, both to Reaſon and Experience.

For the moſt illuſtrious *Newton* has demonſtrated, (in his Opticks, Pag. 311.) that the Denſity of all middle Fluids anſwer in Proportion to the Reſiſtance of thoſe which are next them; and it is a great Miſtake of thoſe who hold, that the Reſiſtance of Projectiles diminiſh *in infinitum*, thro' the infinite Diviſion of the Parts of a Fluid; when on the contrary it is viſible, (*vid. Princip. Lib.* 2. *Prop.* 38. *Coroll.* 2.) for that the Reſiſtance which is occaſion'd by the Diviſion of the Parts of the Fluid, can't be much diminiſh'd; becauſe it appears, (by *Prop.* 40. *Coroll.* 3 & 4.) that

(*) Inane quod vocant Philoſophi nullum eſſe poſſe ſpatium ſine Materiâ, nobis autem ſpatium (ſeu Extenſio) unum & idem eſt atque Materia, & quærere utrum ſpatium ſine materia poſſit eſſe tale, eſt quale ſi quæras utrum Materia ſine Materiâ poſſit eſſe. Vid. *Rohault's* Conſectaria, Pars prim. Cap. 8.

the

the Reſiſtance of all Fluids is as their Denſities; for why can't the ſame Quantity of Matter have the ſame Force of Reſiſtance, when they are divided into a great many ſmall Parts, as a few that are larger? Wherefore, if there were no void Spaces, it would follow, that a Body which is caſt into the Air, or into a Place out of which the Air is exhauſted, ought not to move with leſs Difficulty than in Quickſilver, which is contrary to Experience. And it is plain from the Nature of Gravity, (†) (as before aſſerted) that that Space is an *inane* or empty Space, and ſuch a one indeed as abounds in all ſublunary Things.

When therefore the Eſſence of Matter is founded not in Extenſion, but in impenetrable Solidity; it muſt be ſaid, that the whole World is compos'd of ſolid Bodies, which move in *vacuo:* Nor is there any Doubt to be made; but that the Phænomena's of Nature may be as well explain'd by this Principle, as any; for the Explanation of thoſe Phænomena's, which ſeem to have the greateſt Weight in the Plenitude of the World, as the *Barometer*, the Flux and Reflux of the Sea, the Motion of the Stars, Light, *&c.* are very plainly demonſtrated from them.

Of the ſame Opinion alſo, is the learned Phyſician Dr. *Cheyney*, who in his Principle of reveal'd Religion, (*Cap.* 2. *Coroll* 5. *Pag.* 12.) by the *vis inertiæ* of Sir *Iſaac Newton*, ſays, that the Neceſſity of a *Vacuum*, or a Place diſtinct from Matter is clearly demonſtrable; all Bodies (according to that learned and ingenious Author) reſiſting, to the utmoſt of their Power, any Change or Alteration of their State, whether of Motion or Reſt. And ſince the Reſiſtance in the ſame Body is always equal or the ſame, and in different Bodies (as before-mention'd) is proportionable to the Quantity of Matter they contain; and that ſince, conſequently, if two Bodies, containing equal Quantities of Matter, and moving with equal Velocities in a contrary Direction, ſo that they impinge directly on one another, they will certainly ſtop at the Point of their Concourſe and be at reſt.

As alſo, ſince it is demonſtrable, that two Bodies moving contrariwiſe with equal Celerities, and reſting both at their Meeting, are equally heavy; it neceſſarily follows, that two Bodies containing equal Quantities of Matter, are equally heavy; and therefore, if there were no Vacuities in Bodies, two Spheres of equal Diameters would contain equal Quantities of Matter,

† Vid. Not. 1. Lin. 4. Verum ex Gravitatis Natura conſtat jam omninò aliquod inane & multo id quidem maximum in rebus eſſe.

and

and conſequently be equally heavy; *i. e.* two Spheres of equal Diameters, one of Gold, and another of Wood, ſhould have the ſame ſpecifick Gravity; which being contrary to Experience, there is a Neceſſity of admitting Vacuities in the later Sphere, to anſwer the Difference of their Gravities.

It is true (ſays that learned Phyſician) it may be anſwered that one of the equal Bodies may be ſuppos'd to be more porous than the other, and the Pores to be pervaded by ſome more ſubtle Fluid (ſuppoſe Air) which paſſing freely thro' the Body, is not concern'd in the Impulſe. But to obviate this Objection, and to make the Proof of a *Vacuum* amount to a Demonſtration, Sir *Iſaac Newton* has ſhewn by many repeated Experiments in Pendulums, *&c.* but particularly in deſcending Bodies, that the Reſiſtance of Fluids (as we have already ſet down from the Reverend Dr. *Clarke,)* is always proportionable to their Denſities, that is, to the Quantities they contain, or to their *Vires inertiæ,* which this Phyſician urges from the Reſiſtance and Preſſure of Fluids one upon another: And ſince it is Weight alone (*i. e.* Matter) which can produce Preſſure in all inanimate Bodies, (for which ſee *Newton*'s Schol. on Prop. XL. Lib. II. ſecond Edition of his *Principia)* it is plain, that if Bodies be ever ſo porous, and fill'd with Fluids ever ſo ſubtle, yet if there be no Vacuities entirely without Matter, thoſe porous Bodies muſt be equally heavy with the moſt compact ones; ſince the Fluids requir'd to fill thoſe Pores, muſt be equally heavy with the ſolid Body; and ſince both muſt contain an equal Quantity of Matter, if there be no Vacuities; all Fluids reſiſting (that is indeed weighing) in Proportion to the Quantity of Matter which they contain. If therefore there be no Vacuities, Bodies muſt be equally heavy, which being contrary to Experience, there is a Neceſſity of admitting Vacuities, in order to account for the all different corporeal Weights.

But there is another alſo, of our modern * Philoſophers, who, upon the Foot of the *Newtonian* Principles, allows of the Poſſibility of a *Vacuum,* from the bare Examination of Ideas, for that every Thing which we can clearly diſcover to exiſt, is poſſible.

We acquire (ſays that learned Author) an Idea of Solidity by the Touch, and we feel Bodies that reſiſt us every Moment, by

* Vacuum poſſibile eſſe ex ſolo examine Idearum deducitur, omne enim quod clare concipimus exiſtere poſſe, poſſibile eſt, (ut vult Graveſande. Math. Elem. Nat. Philoſ. Cap. 3. Lib. I.)

which

which it appears that a Body is ſolid; which Ideas of Solidity are transferr'd, even to thoſe more ſubtle Bodies, which, by Reaſon of the ſmallneſs of their Parts, eſcape our Senſes; (as Air for inſtance, in which, as will be hereafter found, are ſeveral vacuate Spaces) and we find by Experience, that even theſe of Air, ſubtle and thin as they are, reſiſt other Bodies as well as the hardeſt.

Thus the Air we are ſpeaking of, does, almoſt, always eſcape our Sight and Touch; yet in a Syringe, which is cloſe ſhut up at the End, it reſiſts the Piſton, ſo that it can't be puſh'd to the Bottom of the Syringe by the greateſt Force.

The Idea of Solidity (as defin'd by this excellent Perſon) is not indeed contain'd in Extenſion; that only follows from Contact, but this may be had without it; for if a Man had never touch'd a Body, he could have no Notion of Solidity.

And indeed all or moſt of the Squabble that has been between the Philoſophers, both ancient and modern, has been occaſion'd by their different Conceptions of the Nature, Properties and Accidents of Matter.

Ariſtotle in his Phyſicks, writes that Matter is *nec Quid, nec Quantum, nec Quale,* neither can it be defin'd in any other certain Manner; from which moſt of his Followers inferr'd, that it was not capable of Extenſion, nor did it even exiſt; tho' *Rohault* in his Phyſicks, *Cap.* 7. *Pag.* 23. ſays, That *Ariſtotle* appear'd to ſpeak of Matter in general Terms; beſides as he there diſtinguiſhes Extenſion from Quantity, every Body ought to diſtinguiſh carefully between them, becauſe one can't know one without the other.

I ſhall omit the Accidents of Matter, which are Hardneſs, Liquidity, Cold, Lightneſs, Taſte, Smell, Sound, Light, Colour, &c. which the *Carteſians* ſuppoſe have no Parts, Figure nor Extent; and laſt of all, as to the penetrable Nature of theſe Accidents: If any Part of Matter, to wit, a Foot cubick, tho' it has all Things that are neceſſary to that Magnitude, yet it does not appear that another Foot cubick can be added, but that of it two cubick Feet muſt be made; and as he that is willing to reduce them by Penetration, both into one cubick Foot, yet neverthleſs could not join one to another, unleſs he ſhould overturn that which he had firſt fix'd; upon which Account it was, that the *Carteſians* believed, that the Parts of Matter are impenetrable in their Nature.

Which Things being ſo, it muſt be inferr'd, that Extenſion, Figure and Impenetrability, are truly the Properties belonging to

the Eſſence of Matter, which conſtantly attend it; and from which it can't be ſeparated: But becauſe Extenſion is to be conceiv'd prior to the other two, and that neither of them can be well conceiv'd or underſtood, unleſs Extenſion be firſt, it is to be ſuppoſ's'd that this Extenſion is that which conſtitutes this Eſſence or Being of Matter.

But Dr. *Clark*, in his Notes on *Rohault*, ſays, That if Extenſion was the eſſential part of Matter, and that that Matter was the ſame as Space it ſelf; it would follow alſo that Matter (as Space) was infinite, and conſequently eternal, which does not depend on created Beings, nor can be any Property or Conſequence of them, much leſs a Mode or Accident, and therefore it muſt be a true Subſtance. * Beſides, (ſays our learned Divine) by the Nature of Gravity, (as before defin'd) by the Motion of Comets, and the Vibration of Pendulums, it appears plainly that Space it ſelf can't be Matter; † and therefore that not Extenſion ſimply conſider'd, but ſuch an Extenſion as is ſolid, impenetrable and endued with the Force of Reſiſtance, can (as before ſaid) be call'd the *Materiæ Eſſentia*, or the real Being or Eſſence of Matter.

Now as the Extenſion of a Body implies a Diviſibility, that is, that one may conſider Parts in it, but yet the Diviſibilty of Bodies differs from the Diviſibility of Extenſion (according to *Graveſande*, Book I. Pag. 8.) for its Parts may be ſeparated one from another; but as this Property depends upon Extenſion, it muſt be examin'd under the Conſideration of Extenſion, and then what is thus demonſtrated may be eaſily transferr'd to Body.

But to come nearer the Point, and not to detain my ſelf nor Readers in a Labyrinth, concerning the Parts whereof Matter is compos'd; it is in general certain, that many of the Particles of Matter are of a very ſubtle inſinuating Nature as Air is, which tho' it does inſinuate it ſelf into all the Crevices and Receſſes, into which it can find Entrance; yet that there are Vacuities, even in Air it ſelf, I ſhall by and by demonſtrate.

By the Help of Microſcopes many Objects, which would otherwiſe eſcape the Sight, appear very large, and there are ſome Animalcula ſo ſmall, that they are ſcarce viſible with the beſt of theſe Inſtruments;

* Ex quo manifeſtum eſt eam à rebus creatis non pendere; nec poſſe earum conſequens, nec proprietatem; multò minùs Accidens, aut modum; ideoque veram eſſe ſubſtantiam. Vid. Cap. 7. pag. 23. prædic.

† Quare non *Extenſio*, ſed Extenſio ſolida, impenetrabilis & vî Reſiſtendi prædita, rectius (ut dictum eſt) appellari poterit Materiæ Eſſentia. Vid. Dr. *Clark*'s Notes on *Rohault*'s Phyſ. Part I. Cap. 7. pag. 22. in finem.

and

and yet theſe have all the Parts neceſſary for Life, as Blood and other Liquids: How wonderful therefore muſt thoſe Particles be, which make up ſuch a Fluid!

But at laſt, and to conclude this Chapter, theſe Parts, however ſubtle they are, are certainly intermix'd with vacuate Spaces, which proceed from the nature of their Figure or the ſtricter Union and Coherence or Incoherence of them.

I imagine therefore that Air is compos'd of an infinite Number of Corpuſcula's, and ſmall Bodies or Particles of Matter interſpers'd thro' the whole Region where we live, of the Nature, (tho' inviſible) of Sponge, Cotton, Hair or Wool, or of that Down which is on the Top of the *Sonchus Levis*, or *Southiſtle*, or of the *Erigerum Tomentoſum* or *Groundſel*, which ſeeds ſo plentifully in Gardens.

Whether the Figure of theſe Particles of Air be globular and ſmooth, or irregular and ſo glabrous or uneven, I ſhall not at this Time take up my Time in diſcuſſing; it is evident, that let them be which you will, and let the Subſtance of them be fram'd in the Nature of any of the Subſtances abovemention'd, that in all the Unevenneſſes that muſt neceſſarily flow from their Contexture, Shape and Figure, there are Interſpaces, wherein that *Vacuum* reſides.

Except we were to ſuppoſe them to be Bodies of the Figure of a Die, us'd in Gaming, which, nevertheleſs, would by their Revolution (had they Room to turn) ſoon wear off their Corners. Nor is it to be doubted, but that thoſe Particles of Air are not very ſtrictly hook'd together, but flie as it were ſeparately and diſjointed one from another; at leaſt if there be any Connection, it is only that, by which the Tops of the Apices or Tufts of theſe Semens are joined to one another; and it may with Reaſon be ſuppos'd, that theſe vacuate Spaces which are diſpers'd between them are larger than thoſe Corpuſcules themſelves are, and much beyond the Reach of Human Sight, and that thoſe Spaces are very intelligibly (by Phiſiologiſts) defin'd by an interſpers'd or vacuate *Inane*.

Agreeable alſo to this, is what the learned and laborious *Harriſon*, in his *Lexicon Technicum*, has ſet down, who has diſtinguiſh'd it into a *Vacuum diſſeminatum* or *interſperſum*, that is, large Vacuities interſpers'd about or between the Bodies of a ſmaller or larger Fluids.

Or a *Vacuum coacervatum*, which is a larger void Space, made by the meeting together of the ſeveral interſpers'd or diſſeminate Vacuities beforemention'd; and that there is in the Senſe of theſe

learned Gentlement, a *Vacuum*, at leaſt a diſſeminate one, ſeems clear from the following Arguments:

First, that without ſuppoſing ſome interſpers'd Vacuities amongſt Bodies, 'tis very hard to account for Motion; for if there be an abſolute *Plenum*, the leaſt Body in Nature can't move, but all Bodies that are muſt move with it; and yet into what Places they ſhould move, when all Things are already full, is very hard to conceive.

Secondly, Without allowing a *Vacuum*, how can there be any ſuch Thing as either Rarifaction or Condenſation; for if all Space is actually full of Body, nothing can poſſibly ever take up a greater or leſſer Room than it had at firſt, and yet we find by evident Experience, that Air is capable of a very great Degree of Compreſſion, and that Water may be rarified into Air or Vapour, and then take up vaſtly larger Room than it did before.

Thirdly, Sir *Iſaac Newton*, (as beforemention'd) has found that the Weight of Bodies doth, by no Means, depend on their Forms or Textures, but that all Bodies at equal Diſtances from the Earth do gravitate towards it, in Proportion to the Quantity of Matter in them, which is every where as their Weight; wherefore there muſt of Neceſſity be a diſſeminate *Vacuum*, for if all Places were full, there would be no Difference in the ſpecifick Gravity of Bodies; but Air would be as intenſively heavy as Gold; and ſo Gold could not deſcend in Air, much leſs any lighter Body than it, which would contradict all the received Laws of Hydroſtaticks, tho' confirm'd by ten thouſand Experiments.

To illuſtrate what we have been ſaying, from Example and Experiment, and to give this diſſeminated *Vacuum* (which is not altogether inconſiſtent with a *Plenum*) its due Emphaſis, ſo as to diſcover its Effects in Hydroſtaticks, we find that the Ancients (as the learned *Wallis*, P. 14. Prop. XV. of his Mechanicks) plac'd their Notion of a *Plenum*, and the Abhorrence which there was in Nature to a *Vacuum* from a Siphon, which being plac'd in a Veſſel full of Water, and the Air drawn out of the Tube (as it is done in the decanting of Wine and other Liquors) that then the Liquor will follow immediately and keep running, till the Veſſel was quite empty, at leaſt till it was drawn down to the level of the End of the Siphon.

From which Phænomenon, it was (ſays he) that they grounded their Belief of an infinite *Fuga vacui;* and that conſequently they could, by the ſame Method, convey Water over the higheſt Hills into oppoſite Valleys; but it was afterwards found out by

undoubted Experiments, that Water could not be drawn above 33 or 34 Foot high at moſt, either by Suction or Pulſion (call it which you will) that that *Fuga vacui*, (as underſtood by the Ancients) had really no Exiſtence but in the Minds of its profeſs'd Admirers.

On this Account it was that ſome Moderns began to introduce the *Equipondium* or Counter-ballance of Air, to that of Water, in the Room of the * *Fuga vacui*, ſo much before contended for; which they found would not do; in which the famous *Gallileo* firſt led the Way, ſhewing the Method of weighing and knowing the ſpecifick Gravity of Air, compar'd with Water, &c. and which was from him purſued with great Sagacity by *Torricelli*, who invented, as a farther Proof of it, the *Barometer*, which from that ingenious Inventor, is to this Day, by the Learned, call'd the *Torricellian* Experiment; being a glaſs Tube of about three or four Foot long and one Quarter of an Inch Bore, ſeal'd and clos'd by Fire at one End, and at the other fill'd with Quick-ſilver, and then being ſtop'd with one's Finger, and having the unſeal'd End of it thruſt down under the Surface of other Quick-ſilver contain'd in any Veſſel, and then the Finger being removed from the Orifice, and the Tube put into an erect Poſture, the Mercury will deſcend or run out, till it remains in the Tube to the Height of between 28 or 29 Inches or more, leaving at the Top of the Tube an apparent empty Space.

I need but juſt add, that this Quick-ſilver, or any other ſpirituous Liquor, thus ſuſpended, has been found to encreaſe or leſſen its Height in the Tube, as the Weather alters for dry or wet; and by this Means it is, that the Weight of Air is known.

To go on with the learned *Wallis* P. 744. Fig. 321. of his Mechanicks, having ſuck'd out the Air at the End of the Siphon E in C, until it has made an *Equilibrium* or equal Poize, by the Preſſure of the external Air, (as has been already noted) ſuppoſe to the Height C I, which admit to be 33 Foot high in Water, (and proportionably, according to the ſpecifick Gravity of all other Liquors) if therefore the Top of the Siphon D be not higher than I, the Fluid will riſe quite up to the Top, and having found out its Paſſage, will deſcend and flow out at E; and will continue always ſo to do, by repeating the ſame Methods.

* *Wallis* Cap. 14. Prop. 11. of his Hydroſtaticks, aſſerts, Quod fugam illam non infinitam eſſe, ſed intra certos limites coerceri; aeriſque Equipondium in illius loco ſubſtituendum, &c.

But by the ſame Rule that E is lower than C (in the *Superficies* A C B) ſo are C and E compreſs'd by the equal Force or Preſſure of the Atmoſphere, if the Leg D E be of leſs Height than the Leg D C, and ſo the Fluid, which is in the firſt gravitating leſs, than that which is in the laſt; the Fluid would be carry'd by a contrary Courſe from E thro' D, even unto C, (the Air ſucceeding in E, except the Largeneſs of the Siphon is ſo great, that the Air might aſcend by the Sides of the Fluid, whilſt it was flowing thro' the End of the Siphon D E,) in which Caſe the Fluid might part in D, and one Part aſcend by D C, and the other by D E, the Air aſcending likewiſe thro' the Sides of the deſcending Fluid D E; but in narrow Siphons the Fluid is or would be carry'd back in E thro' E D C being driven by the urgent impulſive Air in E.

But if D be higher than I, the Fluid will be again forc'd from C, even to I, but no farther, nor will it ever reach to D; and therefore it remains, that the Suction ceaſing, it continually flows thro' D towards E; but ſo as that it can't by any Means be drawn on to E; for when the Suction can't act any otherwiſe than by making a Place where the Fluid may be receiv'd, it is not properly ſuppos'd to be perform'd by Suction, but preſs'd on by the Impulſe of exterior Air; but ſuppoſing that Room be made, the the exterior Air can't, nevertheleſs, drive the Fluid any higher from D than to I, and the Fluid will there ſtand at I; neither can it be carry'd any higher, ſo as that it may paſs thro' D to E, according to the Laws and Principles of Hydroſtaticks.

And indeed, if the whole Siphon E D C were to be fill'd by the Fluid, the Orifices being open in both of them, and a Partition made in D, that which is in the Leg D C would be depreſs'd, ſo as not to riſe higher than I; neither can the Fluid at C be rais'd any higher than the other Parts A B C, and that which is in the Leg D E will flow out thro' E (Air ſucceeding in its Place) at leaſt, except the Leg D E be ſo ſtraight, as that the aſcending Air can't paſs by the deſcending Fluid, in which Caſe the Fluid ſhall deſcend in D E, and then up to the Height I, being there ſuſpended, till the Air can ſenſibly inſinuate it ſelf, and a Way be made, by which the external Air ſhall (by that free Entrance) exerciſe its Force thro' E, and depreſs the Remainder, which was in the Leg D E, even to C.

And here indeed, the whole Story of the ſo long diſputed *Vacuum* and *Plenum* are both brought out, which ſeems to be no more than this, that Air being of an elaſtick Quality, and compos'd of an infinite number of Corpuſcules, which give Way, in

Caſe

Caſe they be compreſs'd or joſtled out of their Places by any other Body harder or more weighty than it ſelf, unbends, looſes and reſtores it ſelf again to its firſt State and Poſition, after ſuch Weights or Bodies abſent themſelves again, and permit it ſo to do; and that this Elaſticity is a Quality eſſential (at leaſt in the Degree Air is) to nothing but it ſelf, there being no Fluid that participates of it, in that Degree, but ſo far as it contains any of its Particles in the Pores thereof, and that the *Fuga vacui* is no other than that Elaſticity with which Air is endued, which eaſily ſubmits to be ſuck'd or drawn up to give Room for Water, which riſes contrary to its own Nature, to the Supply of the ſo much dreaded *Vacuum*, by the Laws of Hydroſtaticks, by the exterior Preſſure of the more weighty Body of the Air of the whole Atmoſphere, combining, as it were, together; and that there is, nevertheleſs, not a Receſs in Nature where Air does not make up towards a *Plenum*, tho' not a real one.

To conclude, as I begun, with the laborious *Bockler*, (in the Enquiry I have been all along making concerning the ſo much diſputed *Vacuum* &c. I can't but obſerve with what Patience and Judgment that exquiſite Author has ſum'd up the Arguments which have been deliver'd *Pro* and *Con*, by the Diſputants on either Side, without ſhewing any Partiality or viſible Diſlike to either; yet he at laſt appears to be a Pleniſt, and when he is giving the Opinion of *Aphrodiſeus*, he is a little warmer, and aſſerts *that there is no ſuch thing as a Vacuum*, as deſcrib'd by the Champions for it; but that *it was contrary to Nature, and that if ſuch a Notion were allow'd, the Heaven and Earth, and all the other Elements would turn to Ruin and Deſtruction;* but this Miſtake of his was certainly owing to the faint Ideas he had of Solidity, Extenſion and the like, of which ſo much has been ſaid in this Chapter that I need not repeat it.

BOOK. II.

CHAP. XIV.

Of Air and its Effects in Hydroſtaticks, by its Gravity, &c.

I Shall in this Chapter omit that Enlargement on the Virtues and Effects of Air, (taken in a vegetative Senſe) as ſuch a noble Subject requires, becauſe it is more properly phyſical, and ſo not altogether relating to the Subject I am upon; however, it may not be amiſs to premiſe, that it is this which falls down and continually hovers on Fruit-trees and other Vegetables, where by the phyſical Operation of Nature it ſelf, meeting with Dews, and other liquid Refreſhments, it cauſes Trees and Plants, and whatſoever it falls on, to flouriſh and grow. Nor is this Union and Mixture of the Superior with the Inferior World, an imaginary, but a real and effective Truth; for from this Marriage (if I may ſo expreſs it) both of Heaven and Earth, is produc'd all the Race of Vegetables, as well as Animals; 'tis this which cheriſhes old Age, and is the Cauſe of that charming Renovation of Youth, which is often viſible in decaying Plants, Trees, and 'tis this which cauſes the Trees to leaf, bud and fruit, and to diffuſe thoſe generous Odours, with which it ſelf is again (by a due and regular Circulation) perfum'd.

Neither ſhall I detain my Reader with any long Account of the great Controverſy, which has happen'd between ſome modern Philoſophers concerning Air; as whether with ſome, it be nothing elſe but thoſe Exhalations which are drawn up out of the Earth, and ſo take Air and the Atmoſphere to be one and the ſame Thing; whilſt others ſuppoſe (that beſides theſe Exhalations) there is hovering about the Earth, a certain peculiar ſimple Body, which they call Air; tho' they likewiſe agree that thoſe Exhalations may

may be chang'd into Air, and on the contrary Air may be chang'd into Clouds and heavy Vapours.

" *Ariſtotle* and his Followers (as it is found in *Varenius's* Prop. " 3. Pag. 324.) divide thoſe Exhalations into two Species or " Kinds, *(viz.)* Vapour and Smoak. Vapours (ſay they) are gene- " rated of Water and eaſily return thereto: But Smoak is generated of " things which are dry; ſo Sal Armoniac being put over a Fire goes " off in Smoak, and this is the Cauſe why different Air is found " in different Countries; alſo why it rains in one Place and not " in another." *(Viz.)* to the Siccity that is in the ſubjacent Body and Bowels of the Earth, from which that Fume is ſuppos'd to ariſe.

AND this Definition of the Air into two Parts does not, I muſt confeſs, ſeem any Way diſagreeable to Reaſon, and the ſmall Obſervation I have made of things, tho' of what Figure thoſe two Parts are compos'd, we are not well inform'd, by theſe or any Authors that are common amongſt us.

THAT Air is of two Kinds, I gueſs from thoſe drying Winds which are ſo prejudicial to all new planted Trees in *March*, when the Siccity or Dryneſs of it, is ſo predominant, as to deſtroy all the milky Fibres of a Tree, and whatſoever elſe it meets with that is young and tender; from which I ſay, I am convinc'd that Air and Vapour are two things; the firſt I take to be of the Figure of little Fleeces of Wool, which are always fluctuating up and down, in this otherwiſe *Inane* or empty Space, which Air is either more or leſs ſubtle or denſe, according as the Nature of Heat and Cold is more or leſs, or that the Weather is in an intermediate State betwixt both.

THUS in the greateſt Colds of Winter the Air is ſubtle and ſerene, whilſt a more moderate Cold contracts and makes it more heavy and denſe: Now it is the Denſity of the Air below, which raiſes up and ſuſpends the Vapours above it; namely, till they ſettle in thoſe Regions which are ſpecifically equal to themſelves in Weight, and this ſeems to be one Reaſon why (in high cutting cold Winds) the Air is ſometimes dryer, than it is at others. And a ſecond Reaſon may be, that as the Denſity of the Air ſuſpends thoſe Particles of Vapour (which is lighter than itſelf above) ſo it depreſſes all thoſe which are below from riſing; ſince it is demonſtrated from the honourable Mr. *Boyle* in Paradox or Propoſition viii. Chap. 12. of this Treatiſe; *that Water* (and I may add any other Fluid) *may be made to depreſs a Body lighter than itſelf as well as buoy it up.*

But whatever that be, it is as *Rohault* Part 3. Chap. 2. of his Phyſicks (as turn'd into *Latin* by the Rev. Dr. *Clarke*) has ſet down, that liquid tranſparent Matter which ſpreads itſelf upon this Globe of Earth and Water whereon we live, and that it muſt of Neceſſity be compounded of an innumerable Quantity of Particles of no certain Shape or Figure, ſpreading irregularly like the Boughs of a Tree; and that the Lightneſs of thoſe Particles is ſuch, that they are continually in Agitation, and tho' their Figure ſeems to be ſuch and ſo diſpos'd, that as often as they meet in Contact they might be join'd one to another; yet becauſe of its Tenuity or Thinneſs, or from thoſe other Particles of Matter which are continually preſſing upon them, from the upper Regions, they are with the greateſt Eaſe unbent and unfolded.

But becauſe this Account of *Rohault*'s, (tho' finely drawn) ſeems to be rather phyſical than any Way mathematical; I ſhall ſubſtitute an Account of my own in the Place of it.

I imagine then that Air is compos'd of an infinite Number of corpuſcular Atoms or rather fine tranſparent Threads or Fibres, (as before obſerv'd) like the ſmall Filaments or Threads of Wool, Cotton, or any other hairy or tomentous Subſtance, or perhaps rather like thoſe of Down, which grow on the Heads of many Garden Seeds, or the fine Icicles of a hoary Froſt, the Shape of which is by ſome compar'd to the ſmall irregular Branches of a Tree, containing in their Interſpaces the Place where this *Vacuum diſſeminatum* (if I may ſo expreſs it) reſides.

That theſe Particles of Air conſider'd by themſelves have no centrifugal Force, nor do they cohere to one another is evident by that eaſy Tranſition that is made by the Impetus of any ſtronger Body through them; for tho' by their Figure they may ſeem well diſpos'd for ſuch an Union; yet this never is effected on Account of the Thinneſs of that divided Matter of which they are compos'd, the Branches alſo being ſo ſhort and thin, that they can't well be knit together; that this Air is always liquid and never grows hard as congeal'd Water does; that it is light is becauſe there is a great Rarefaction in it, and that it is tranſparent muſt of Neceſſity be, that thoſe Rays of Light which proceed from the Sun may have their free Paſſage, all which are amongſt the Suppoſitions of all who have wrote of Air.

But of whatever Parts or Particles of Matter Air is, it is when compos'd and taken together call'd the Atmoſphere, an Appellation well known and often made uſe of in hydroſtatical Experiments,

periments, and is no other as * *Varenius* has it, than the Texture or weaving of an infinite Number of Corpuſcules which adhere to, or I may add rather, hover about the Earth as the Down does on the Coat of a Quince. *Graveſande* in Book 2. Part 3. Chap. 12. of his mathematical Elements of natural Philoſophy tells us, that tho' Air is corporeal and heavy, yet (agreeable to what is before ſet down on this Head) its Parts yield to any impreſs'd Force, and are very eaſily mov'd one againſt another; that it preſſes in Proportion to its Height, and that that Preſſure is every where equal; it is plain therefore that it ought to be reckon'd amongſt the Fluids and admits of the following Definitions.

DEFINITION I.

All that Air with which the Earth is encompaſs'd, conſider'd together, is call'd the Atmoſphere of the Earth, or ſimply the Atmoſphere only.

DEFINITION. II.

The Height of the Air above the Earth is call'd the Height of the Atmoſphere.

That Air is a Body appears from its Excluſion or rather reſiſting all other Bodies, from the Place where it is in its compreſs'd or contracted State; for tho' it will ſuffer itſelf to be compreſs'd, yet you can't with any Force, force it from any included Place, except you break the Veſſel, as is ſeen in the Piſton of a Syringe *&c.*

That it is heavy is prov'd by its preſſing upon the Surfaces of other Fluids, and the ſuſtaining them in Tubes, that it yields to any Impreſſion and has its Parts eaſily mov'd, is alſo plain.

Of this Atmoſphere (or the Air in it) it is generally ſuppos'd that the ſupreme Parts are more ſubtle than the inferior, but it often happens, that the middle Parts are more denſe than thoſe which are loweſt and neareſt the Earth. Firſt, becauſe the lighter Particles ſeeking the higher Place, they are therefore the more ſubtle and light. Secondly becauſe thoſe Parts or Particles eaſily get together in the middle of the Air, and ſo become thick and heavy, eſpecially when the warm Particles of Air which are car-

* Itaque Atmoſphæra & Aer nihil aliud eſt quam textura multorum Corpuſculorum, quæ Telluri adhæret; ſicut Lanugo Pomum Cotoneum circumveſtit. vid. *Varen.* Geograph. general. Sec. 5. Prop. 3. Pag. 324. of the Elziver Edition.

ried up along with them leave or defert them, and the Rays which are refracted from the Earth in that middle Region, have no Force becaufe of this Diftance; and from this it comes to pafs, that after Rains the middle Air (which as has been before obferv'd, is of the fame fpecifick Gravity of Vapour) is more ferene (to wit) becaufe the thick and heavy Parts are feparated from it.

IT has been a Queftion held in Debate amongft the Philofophers, *whether the Atmofphere or Altitude of the Air above the Earth, be one and the fame in all Places, and whether its Figure be fpherical or not?* That it fhould not be the fame, but that there fhould be different Altitudes in different Places, feems to follow from this, that the Sun is only vertical in one Place and at one Time, and that it fhines obliquely, and therefore but faintly in other Places which are nearer its Body, and the polar Influences; and therefore the Power of the Sun's Rays in the Elevation of Vapours is different, and confequently the Vapours themfelves are lifted to different Heights; to wit, in Places to which the Sun is vertical, there fhould be the greateft Height, in the oppofite Pofition the leaft, and in Places about the Pole they fhould be midling, even fo as that the Figure of the Atmofphere fhould be ovular; and fo does *Cartes* Lib. xiv. by a peculiar Method endeavour to explain.

BUT how fpecious foever at firft Sight this appears to be, it is contrary to Truth (to wit) *that Truth that the Altitude of the Atmofphere is the fame in all Places,* and that not only *in all Places,* but alfo *at every Seafon of the Year*; in the Summer as well as the Winter it remains conftantly the fame, as whoever will take the Pains may find clearly prov'd by *Varenius* in the 5th Section of his *Geograph. general.* Prop. xiv, xv, xvi. where it is demonftrated that what *Archimedes* has faid of Water is alfo applicable to Air; for that that Part of Air which is lefs prefs'd is expell'd by that which is more; every Part therefore of Air is prefs'd upon by the Air which is above it, which is the Caufe why the Figure of the Atmofphere is fpherical and not ovular; neither does the Condenfation or Rarefaction of Air change its Altitude, becaufe 'tis not the whole Atmofphere which is condens'd or rarified at once, but fome Part only, fometimes this, fometimes that, and fometimes the other. The only difference feems to be this, that this Condenfation may be greater at one Time than another, but this Difference can encreafe its Altitude but little.

AND

AND as to its being higher in the Summer than the Winter in this Country (becauſe our Air thereby is attenuated and made lighter in one Seaſon than in the other) there is nothing in it; becauſe tho' it be Winter here, it is Summer in other Places, on which Account it is, that Part of our Air is mov'd towards the Air of other Places, where the Air is not ſo high; and on the contrary whilſt the Air of our Country is depreſs'd by the Cold of our Winter, Part of it moves to thoſe Places where it is then Summer; (to wit) until the whole Air is equidiſtant from the Center of the Earth.

THE ſame Reaſon prevails by Day and Night, for whilſt the Air is contracted with us in the Night, it is rarified more in another Place, and ſo the Air of our Country is mov'd again till it is again brought to a ſpherical Figure; all which by the by muſt be the Occaſion of the Fluctuation and Reſtleſsneſs which is in Air, ordain'd as it is by that great Author and Architect of all Beings, whoſe Works are Wonderful.

THE ſame Reaſon alſo takes Place in Clouds and Rains or Vapours, which are made in this or any other Country; for by theſe it may be ſeen that the Altitude of the Air ought to be more or leſs depreſs'd; but that I anſwer, that there is no Time but when it rains in one Place or another, and becauſe it does rain in any one Place, the Air is never the leſs lightened thereby, as it was not when it rain'd in ſome other Place, diſtant from it before; and ſo the Reaſon is the ſame, and the Quantity of Air not encreas'd or diminiſh'd.

THERE have been † ſome who have been ſo curious as to enquire into the exact Altitude of the Atmoſphere, as whether it be 5, 10, 20, or 30 Miles more or leſs, all which is according to the Denſity of the Air in the different Regions of it, which *Varenius* Lib. 1. Prop. xviii. tells us is of three different Kinds, the middle is colder than the firſt and third, but that third is chiefly compos'd of the moſt ſubtle Air of all, and ſo is conſequently very light and thin. It has been intimated before, that if the Air was equally denſe, a Column of it taking up 800 Times the Space as Water does, would reach above four Miles high, but as it is ſo very thin in the upper Region it is difficult to tell how high the Atmoſphere is extended, perhaps 10, 20, 30, or 40 Miles, ſince Air without the extraordinary Help of Heat may be extended as 14 to 1.

BUT to come nearer the Point in Hand, the Effects that ſuch Mutations of Air and Weather (as has been before mention'd)

† Monſieur *Gobart* ſays that the Atmoſphere is 37000 Foot high.

has

has on all hydroſtatick Calculations, eſpecially that of the Barometer, Themometer, *&c.* are very extraordinary, ſuch I mean as are or have not been accounted for.

For by the laſt Inſtrument, to wit the Thermometer, is plainly ſhewn (as *Varenius* Prop. 8. Pag. 328. *prædict.* ſets down) that it is by the Heat or Temperature of the Air in hot and cold Weather, that we take our Meaſures from, in which we ſee that the heavier Air becomes, the leſs Room Water takes up in the Glaſs, as alſo by how much the hotter Air is, the more Room it requires; the true Reaſon of the different Gravity of Air and its Effects in the Barometer Dr. *Deſaguiliers* (in his Notes on *Ozanam*'s Hydroſtaticks and in other Places) gives in theſe, or Words to this Purpoſe.

" That the Vapours do not (as is or has been ſuppos'd) in-
" creaſe the Gravity of the Air, ſeems more than probable on this
" Account; namely, that when the Vapours are in the lower Re-
" gion of the Air, as in rainy Weather, then the Air is lighteſt,
" as appears by the falling of the Spirits in the Barometer *&c.*
" And when the Vapours are in the middle Region of the Air,
" that is, when the Clouds are high, they don't encreaſe the
" Preſſure of the Air; for altho' the Air be heavier then, it is
" not becauſe the Clouds are high; but the Clouds are high, becauſe
" the Air on which they are ſuſpended is heavy; for when the
" Air near the Earth is more denſe than uſual, then it becomes hea-
" vier than the Vapours which muſt then aſcend, and at laſt ſet-
" tle in the Regions of the Air, which is of the ſame Gravity
" with themſelves.

" If the Vapours were the Cauſe of the Encreaſe of the Air's
" Gravity, there muſt be as many Vapours in the Air at a Time,
" as are equal in Weight to three Inches of Mercury; for ſo
" much we find the Mercury riſes or falls in the Weather-glaſs.
" Now Mercury is about fourteen Times heavier than Water,
" and conſequently there muſt be in the Air at once as many Va-
" pours, as are equal to a Column of Water of 42 Inches, and
" whoſe Baſe is equal to the Surface of the Earth; and he con-
" cludes that the Reaſon why Air is heavier at one Time than
" another, ariſes more probably from there being more Air on
" that Part of the earthy Surface when the Air grows heavier,
" and this proceeds from Winds; for Example, if the Wind (which
" as the Doctor ſays) is nothing elſe but a Stream of Air, ſhould
" blow on any Place, and the Air thus mov'd ſhould be pent in
" that Place by Mountains or Hills: Or if two contrary Winds

" ſhould

" ſhould blow on the ſame Place, in either Caſe the Air will " be heap'd up in the Middle; and conſequently there being more " Air its Gravity will encreaſe; but if the aforeſaid Circumſtan- " ces or the like don't happen in any particular Country, then " the Air which is over it will grow leſs in Quantity and conſe- " quently lighter. Whence it is plain, that Winds are the only " Cauſes of the Variation of the Air's Gravity.

From this general Account of Air I proceed to ſeveral things which are more particular.

Firſt, that the Superficies of all Fluids are preſs'd by Air, and in this conſiſts its Gravity (the Subject of the preſent Chapter). And this among other Experiments, which are and will be produc'd, is found out by the Air-pump; for if you lay your Hand on the Mouth of a ſmall Receiver, and by the Pump draw out the Air, your Hand will ſwell in the Receiver, and after a few Suctions the Air will preſs upon your Hand ſo that you cannot raiſe it.

Secondly, If you take a drinking Glaſs and turn it down into Water, the Air being turn'd out or rarified by burning of Paper &c. If the Glaſs be rais'd perpendicular on its Mouth and put into a Baſon or Bowl of Water, the Water within the Glaſs will aſcend higher than the ſtagnant Water which is in the Baſon without, provided the Glaſs be longer or above that ſtagnant Water.

Upon theſe Principles diving Bells are alſo made, by which Seamen deſcend into the Sea and fiſh up Gold and other Goods loſt in a Wreck; for in that you may breath freely under Water, yet the farther the Bell ſinks the more the Air will be compreſs'd. When it is about 33 Foot under Water, the Air will be compreſs'd to half the Space in which it was before; which often breaks the Blood-veſſels of thoſe which are therein, and makes them bleed at Mouth, Noſe and Eyes.

Thirdly, If you tie a Bladder to the Mouth of a Receiver, and extract the Air; then the internal Air will depreſs the Bladder ſo much, that Man's Strength will not be able to ſuſtain it.

Fourthly, Invert a Receiver, and tie a Weight to the Neck of a Bladder over the Mouth of the Receiver, and hanging on the Outſide of it; having driven the Air out of the Receiver, the outward Air will ſo preſs on the Bladder, as to thruſt it up into the Receiver, and raiſe the Weight.

Fifthly, Take a Piece of Glaſs, and put it on the Mouth of a Receiver, having drawn out the Air, and the Weight of the incumbent

cumbent Air will break the Glaſs; by which it appears that Air preſſes every Way; and which is alſo prov'd by the ſtrong Cohæſion there is of two flat Pieces of Glaſs or Marble exactly poliſh'd and ground together; as alſo by a glaſs Recipient's ſticking ſo cloſe to the Plate after the Exſuction of the Air, that it requires a conſiderable Weight to repulſe it away.

Sixthly, In the *Torricellian* Experiments, if the Tube with the Mercury be put into a long Receiver, the Mercury will fall down at the Exſuction of the Air, and if in the Tube there be left a ſmall Bubble of Air, that Bubble will expand itſelf and fill the whole Capacity of the Tube, even ſo as to depreſs the Surface of the Water, under the Surface of the ſtagnant Water, and a flavid or yellow Bladder, after the Preſſure of the external Air is taken off, dilates itſelf as far as it can.

Seventhly, The Expanſion of the Air in a Bladder, will raiſe a Weight after the external Air is taken away; and a Bladder in which Weights are put to ſink it under Water, will riſe with its Weight after the Extraction of the external Air; alſo a Piece of Cork to which is tyed juſt ſo much Weight as to make it ſink all under Water, except the Surface of it, after the Air is extracted will riſe higher, but when you let in the Air again it will immediately ſink towards the Bottom.

Eighthly, A glaſs Bubble in which is left juſt ſo much Water as will ſink it, after the Extraction of the external Air will riſe; and if you draw out the Air from a ſquare Bottle, the Weight of the incumbent Air will break it to Pieces; alſo if you put ſuch a Bottle ſo cloſely ſtopt, that none of the Air can get out of it into the Receiver; after you have drawn out the external Air, that which is in the Bottle will ſo dilate itſelf as to break the Bottle.

Ninthly, If you take a glaſs Bottle half full of Water, having a glaſs Tube cemented in the Neck of it, one End of which is below the Surface of the Water, and the other being above the Top of the Bottle, has a braſs Top with ſmall Holes in it, if you put this into the Receiver and pump out the Air, the Air in the Bottle will dilate itſelf ſo, as to preſs on the Surface of the Water, and raiſe it up in Spouts through the Holes of the Tube like a Fountain.

Tenthly, I ſhall only add two other Obſervations of Dr. *Deſaguiliers* (and others who have expatiated on Air) which relate to Sound, by which the wonderful Properties of it are plainly diſcover'd.

If you put any Animal into the Receiver, and pump out the Air, the Animal, let it be a Toad, a Mouſe, Dog, Cat, or whatever elſe will go thereinto, it will by Degrees languiſh and in a little Time die; and if you put therein a Bell ſo rais'd on a wooden Frame, that it may have Room to move into the Receiver, and pump the Air out; then if you ſhake the Pump ſo as to move the Bell, you will hear very little Sound from it.

In the Paragraphs beforegoing are abſtracted the wonderful Effects of Air as they diſcover'd by the Pump, the following are very plain and common Experiments, proving the Gravity of the Air deduc'd from the learned *Graveſande*, Book 2. Part 3. Chap. xii.

Experiment 1. *(Fig* 1. *Tabula ſeq.)* Take a glaſs Tube A B, about three Foot long, and about $\frac{1}{4}$ of an Inch Bore; if you ſtop up the End A, and let the Tube be fill'd with Mercury, and let the other End be immers'd in a Veſſel full of Mercury, the Mercury will be ſuſtain'd at the Height of about 29 Inches *Engliſh*, or, as *French* Writers ſay, about 26 or 27 in *Paris* Meaſure; for the *French* Foot exceeds ours. This Riſe is occaſion'd by the Preſſure of the Air on the Surface of the Mercury in the Veſſel, which cannot preſs equally in every Part of it, unleſs in the Tube where no Air is, there be a Column of Mercury which preſſes equally with outward Air.

Experiment 2. *(Fig.* 1. *Tab. ſeq.)* That this Preſſure may not be chang'd when the Tube is inclin'd, it is requir'd that the Mercury ſhould keep the ſame perpendicular Height. If therefore there be two Veſſels containing Mercury, in which Tubes in the Manner abovemention'd are immers'd, of which E D is inclin'd to the Horizon, the Mercury is ſuſtain'd at the Heights *h f* and *i g*, ſo that *f* and *g* are in the ſame horizontal Lines; ſuppoſing the Surfaces of the Mercury in the Veſſels to lie in the ſame Plane.

Experiment 3. *(Fig.* 2. *Tab. ſeq.)* The ſame Preſſure of Air ſuſtains the Water in the glaſs V. which is immerg'd in Water and fill'd with it, and then is pull'd out all but the Orifice which ſtill remains immers'd. And in the ſame Manner Water will be ſuſtain'd, even to the Height of 32 or 33 Foot; for Mercury or Quickſilver being 14 Times heavier than Water, a Pillar of Water a little more than 32 Foot high preſſes equally with a Column of Mercury 29 Inches high, which Preſſure is equal to the Preſſure of the Atmoſphere.

To determine then the Height of this Atmoſphere, or, in other Words, to know how high a Column of Air muſt be that is equal to 28

or 29 Inches of Mercury, or 32 or 33 Foot of Water; we muſt ſuppoſe as it is indeed found by Experiments, that Air is to Water as 800 to 1: Suppoſing then that the Denſity of the Air was equally the ſame from the Top to the Bottom of the ſaid ſuppoſed Pillar, then the Height of the Atmoſphere would be 25600 Foot; but as the higher or upper Part of the Air is ſuppos'd to be lighter, or in other Words more rarified, than the lower Air is which is thicker and denſer, and as ordinary rarified Air to common Air is, by *Marriotte*, ſaid to be as 16 to 4, the Height of the Atmoſphere, if you add them together and take the Medium, muſt be 256000 which is about 4 Miles $\frac{3}{4}$; † tho' Monſieur *Gobart* ſays, it is 37000 Foot high, which is above 7 Miles.

But whatever it be, it is on this Calculation of the Air's Preſſure that depends all the Rules for raiſing Water by Pumps or other Engines, and that that which was heretofore call'd by the hard Names of Attraction, *Fuga Vacui*, and other Appellations, is really no other than Pulſion or the exterior Preſſure of Air.

To proceed, *the Preſſure of the Air depends upon its Height*, as may be eaſily deduc'd from what has been ſaid; but it is more immediately prov'd by carrying the Tube with the Mercury beforemention'd to any high Place; for when you carry this Machine up a Hill, for every 100 Foot you riſe (as ſays *Graveſande*) perpendicularly, the Mercury deſcends a Quarter of an Inch: And *Marriotte* in his Diſcourſe, on the Equilibrium of Fluids, ſays, that if you carry a Barometer up to the Top of a Mountain or a very high Tower (how high he does not ſay) the Mercury will fall by little and little, till it comes to 24 or 25 Inches; and if you go down into a Cave or Mine, it riſes by little and little according as you deſcend, being ſucceſſively preſs'd by a greater Quantity of Air.

That Air preſſes equally every Way, appears from this, that this Preſſure is ſuſtain'd by ſoft Bodies, without any Change of Figure, and by brittle Bodies without breaking; tho' this Preſſure be equal to the Preſſure of a Pillar of Mercury of 29 Inches, or a Pillar of Water of 32 Foot; any Body may ſee that nothing can preſerve thoſe Bodies unchang'd, for the Preſſure on all Parts is equal; but it is plain that the Air does preſs in that Manner; for if you take away the Air on one Side, the Preſſure

† Columna Aeris perpendicularis extenditur ad Altitudinem 37000 Pedum, collateralis extenditur ultra 10000. vid. *Paragraph.* 2. *Pag.* 76. *Philoſoph. Tract.* de Barometro.

is ſenſible on that which is oppoſite to it, as has been demonſtrated under the Head of Hydroſtaticks, but is made more plain in this Place.

To go on to the laſt Experiment (*Fig.* 3. *Tab. ſeq.*) Hang a glaſs Tube to one of the Scales of a Ballance A B, which is ſhut at D, and three Foot long; fill this Tube with Mercury, and let the End E be immers'd in the Mercury that is contain'd in the Veſſel V; the Mercury by the Air's Preſſure is ſuſtain'd at the Height *f* in the Tube, and the upper Part of the Tube F D is left void of Air to make an Equilibrium: You muſt put into the oppoſite Scale a Weight equal to the Tube and the Mercury contain'd in it; the Mercury in the Tube cannot preſs the Ballance, for its Action againſt the Sides of the Tube is horizontal; but the Air acts upon the upper Part of the Tube, and the Column that is ſuſtain'd by the Tube is equiponderate with the Mercury that is contain'd in the Tube: If letting the Mercury run out, you ſuffer the Air to come in, then nothing but the Tube weighs down the Scale; which proves that the Action againſt the inferior Surface of the upper Part of the Tube deſtroys the Action on the exterior Surface, and that the Air preſſes upwards and downwards with the ſame Force; and by this Experiment alſo is confirm'd what has been ſaid of the Air's Gravity; and thus far by ordinary and common Experiments in glaſs Tubes, from whence alſo are calculated ſeveral Inſtruments whereby the Gravity of the Air is ſo ſenſibly diſtinguiſh'd, as that it foretells Change of Weather and the like, to which Uſe the *Torricellian* Experiment is chiefly apply'd. But this I ſhall reſerve for the next Chapter.

BOOK. II.

CHAP. XV.

Of ſeveral Inſtruments whereby the Principles of Hydroſtaticks are more fully explain'd.

IT has been already intimated, that what has been ſaid in the foregoing Chapter of Mercury or Quickſilver, holds true likewiſe in reſpect of other Fluids. On which Account it is that I ſhall, for the farther Illuſtration of this Subject, produce in this Chapter all, or moſt of thoſe Inſtruments by which the Principles of Hydroſtaticks are explain'd.

IT is then obvious (*Fig.* 12. *Tab. ſeq.*) that the Air being ſuck'd out of the Siphon, through which Wine and other Liquors are decanted (as *Wallis* Prop. xv. *Fig.* 321. of his Mechanicks ſets down) at E the Wine or other Liquor in the Veſſel, A B F G will be thruſt up by the Preſſure of the Air upon the Surface A B, into the other End H of the Siphon apply'd to the ſaid Surface, and the Wine will be thruſt upwards in the Siphon, till the Weight thereof comes to an Equilibrium with the Preſſure of the external Air, ſuppoſe till it comes to the Height C I. If therefore the Top D of the Siphon be not higher than I, the Wine will riſe to the ſaid Top of it, and there finding a Vent or Paſſage down the other Leg of the Siphon D E, it will go that Way, and ſo run out at E; continuing ſo to do, (the Cauſes ſtill continuing) till the Veſſel is emptied. But it is to be obſerv'd, that the Mouth E of the Siphon muſt be lower than the Mouth H; for elſe E and H being equally preſs'd by the Atmoſphere, if the Leg D E be but of an equal Length with D H, and conſequently the Fluid in one Leg of equal Gravity with the Fluid in the other; the Fluid would ſtay in the

2

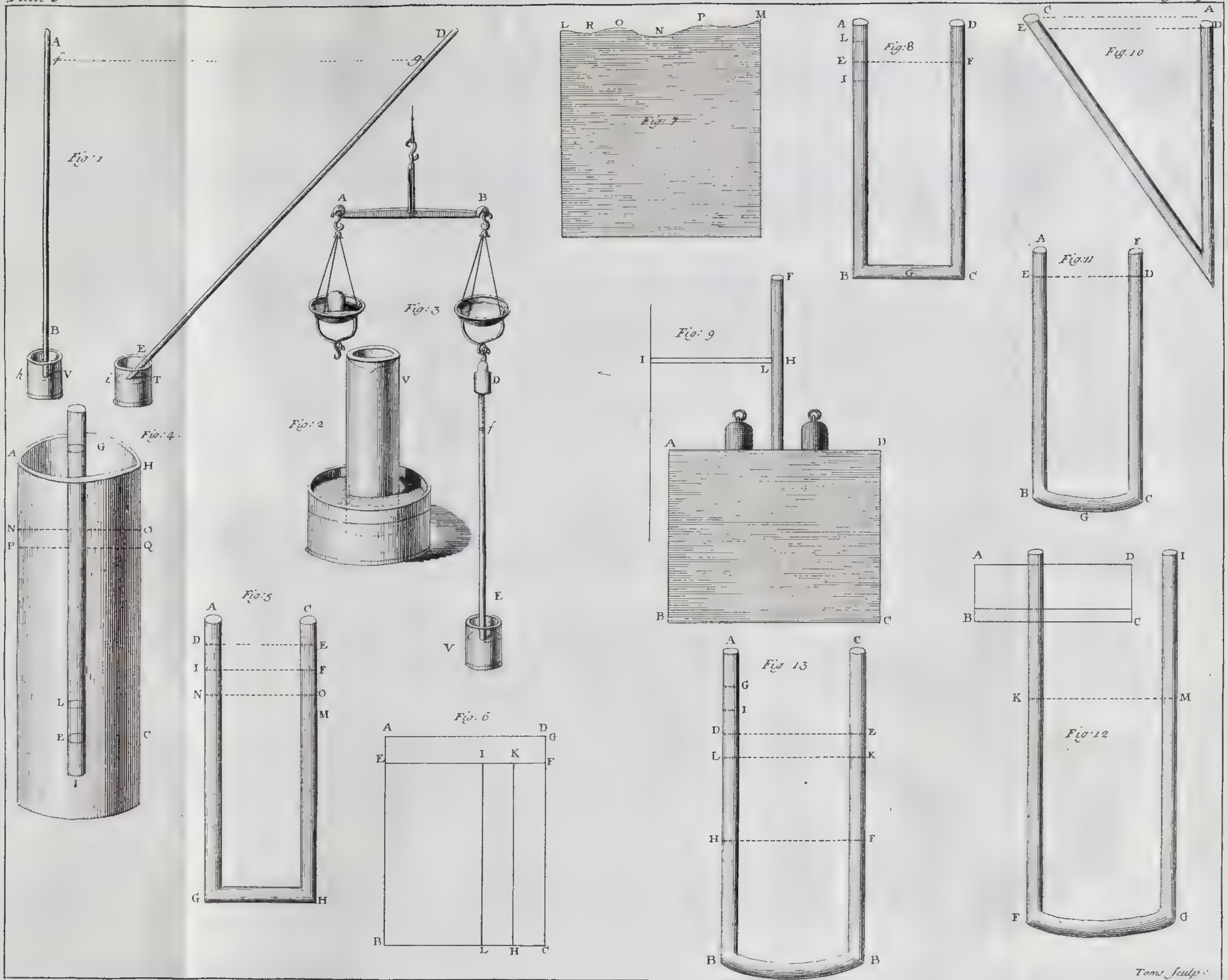


Fig: 1
Fig: 2
Fig: 3
Fig: 4
Fig: 5
Fig. 6
Fig: 7
Fig: 8
Fig: 9
Fig. 10
Fig: 11
Fig: 12
Fig 13
Toms sculp:

the Siphon, not moving one Way or the other, without ſome external Force beſides the Air. And by Parity of Reaſon, If D E be ſhorter than D H, the Fluid would run (not from H to E, but) from E to H, the Air coming up at E, and thruſting the Fluid forward the contrary Way. This would certainly happen, except at leaſt the Siphon be ſo wide, as that the Air may aſcend by the Sides of the Fluid, while the Fluid itſelf deſcends in D E.

I might in this Place give a more particular Deſcription of the Siphon and its Uſes and Improvements, but that I have in the Books wherein I have treated of Hydraulicks appropriated a Chapter entirely to that Purpoſe; on which Account I ſhall not enlarge upon it here, but only obſerve, that by this it is the Notion of a *Vacuum* is deſtroy'd, tho' ſome of the Ancients endeavour'd to eſtabliſh it hereby; for that this ſo much contended for Opinion, which is ſometimes alſo call'd *Fuga vacui*, is no other than that by the Exſuction of the Air at E, the Water aſcending contrary to its own natural Propenſion to I, by the external Preſſure of Air; tho' even then it is certain it will not riſe to above 33 or 34 Foot at moſt; but of that more in its proper Place.

THE ſame thing happens in the Pump (*Fig.* 13. *Tab. ſeq.*) where if the Height C D were greater or not leſſer than C I, which happens by the Preſſure of the external Air, the Water would not aſcend through D, neither would C be preſs'd any farther than the other Parts of the Superficies A C B, and the whole Labour of the Pump would be in vain and of no Effect: But if D be below I, the Water will aſcend through D even to I, if there be no Stoppage or Hindrance even up to the Handle if it be not higher than I; and if you move again the Handle it will overtop F and G, and riſe even to I; yet ſo that if the Handle is let down again, the Water will ſubſiſt at I, whilſt there is more coming up through F and G, the Valve G being ſhut at the Depreſſure of the Rod or Piſton, and then the Water will run out with great Violence at H.

MUCH more might be ſaid under this Head, to demonſtrate that this whole Proceſs is effected by the Preſſure of external Air, but that I ſhall have Occaſion to mention it ſo often in other Places; but I can't but note (before I quit this Part of my Chapter) an Error that *Wallis* himſelf, and after him the learned Dr. *Wells* Rector of *Coteſbatch in Leiceſterſhire*, lately deceas'd, are guilty of, when they affirm that ſuch Wells as have their Water lying very deep, can't have it rais'd by a Pump, but

by

by a Bucket and Rope; becaufe, fay they, according to thefe Principles of Hydroftaticks, the Diftance between the Water at C in the Well and the Valve E (or Bottom of the Sucker when at the loweft, *viz.* at E) muft not be greater than the Altitude, whereto the Preffure of the Air is fufficient to make the Water rife, which is found by Experience to be about 33 Foot.

AND *Wallis* * exprefly tells us in Pag. 746. of his Mechanicks, that Water can't either by a Siphon, Pump, Syringe or any other Inftrument whatever, (for the fame Reafon holds good in all) be rais'd above 33 or 34 Foot; when on the contrary we have Pumps that raife Water commonly 50, 60, 70 or 80 Foot, and Mr. *Fowle* and Company have one that will raife it 120, as may be feen in their printed Papers; tho' all the while it muft be own'd, that the external Preffure of the Air will not rife it to above 33 or 34 Foot, which fuppofe to be F G; nor do our Pump-makers ever fix that Valve or Clack at above 25 Foot high above the Water; but then a long Rod or Pifton of 50, 60, 70, or 80 Foot may be added, which will by the Repetition of the Stroke and by the fhutting of the Valves at G and E, mount the Water to almoft any Height, the Water afcending by the Sides or through the middle of the Bucket or Sucker all the while. But how this is done, will be more particularly fet down when we come to the Practice of Pumps.

BUT to refume our Subject from which this laft Obfervation has been a kind of a Digreffion, Dr. *Defaguiliers* Prop. xix. Pag. 121. of his Lectures on experimental Philofophy fays, that the Afcent of Water, even in a Syringe, arifes alfo from the Preffure of external Air, *(viz.)* when the Tube of a Syringe is immers'd in Water at *q*, (*vid. Fig.* 14. *Tab. feq.*) the Pifton being brought to R S, is left void of Air, fo that the Gravity of the external Air preffing upon the Superficies *o p*, will make the Water afcend in the Tube as high as R S, *(viz.)* that the Part of the Superficies of the ftagnant Water at *q*, may be prefs'd by the incumbent Water in the Syringe with the fame Force, as the Superficies *o p* is prefs'd by the incumbent Air.

THE fame Effects happen by the Help of the Æoliple, the Invention of Father *Merfennus*, as the aforefaid *Wallis* mentions

* Hinc eft quod Hydrargyrum non poffit Siphone, antliâ, Syringâ (nam & illis eadem eft Ratio) aliove Suctionis organo quocunque ultra Pedis Uncias 29 in altum trahi, nec Aqua, ultra Pedes 33 aut 34 circiter, aliaque Fluida pro fuâ cujufque Gravitatis Ratione &c. Vid. *Wallis* Prop. xv. Cap. xiv. Pag. 746. of his Mechanicks.

Pag.

Pag. 736. *predict.* which Dr. *Deſaguiliers* Pag. 119. Prop. xviii explains in the following Manner.

WHEN a Man (ſays he) by the Muſcles of his Breaſt enlarges the Cavity of the Thorax, then the external Air finding Room wherein to expand itſelf, ruſhes in at his Mouth into his Lungs; ſo that if one Orifice of a Cube be in his Mouth, and the other immers'd in Water, then that Part of the Superficies of the Water, which is under the Tube, is free from Preſſure; and ſince the other Parts of the Water are preſs'd by the ſuper-incumbent Air, ſo that the Superficies of the Water is preſs'd by the ſuper-incumbent Weight of the external Air, it muſt needs be that the Water will aſcend up the Tube, to wit, that the Parts under the Tube may be equally preſs'd by the incumbent Water, as much as the reſt of the Superficies of the Water is preſs'd by the incumbent Air; ſo that the Preſſure of the external Air upon the Superficies of the reſt of the Water, is the Cauſe that the Water aſcends up the Tube. *Vid. Fig.* 16. *Tab. ſeq.*

ANOTHER Experiment this curious Gentleman makes uſe of (for which ſee Pag. 120. Plate the 6th. *Fig.* 15.) is to take a Glaſs with a narrow Neck, but without any Bottom as C, put a Tube in its Neck at B and cement them; then tie a Lamb's Bladder to the End of the Tube within the Glaſs, and a large Ox-bladder D over the open End of the Glaſs, ſo that the Bladder may be forc'd inwards, and drawn outwards; you will obſerve all the Air within the Lamb's Bladder wherein the Tube is inſerted will be expell'd; if you draw the Ox-bladder outwards, the Air will ruſh again into the Lamb's Bladder; after this Manner Reſpiration is perform'd, the Air in the Cavity of the Thorax acts on the Lungs, juſt as the Air in the Ox-bladder does on that of the Lamb's. If the open End of the Tube be immers'd in Water, and the Ox-bladder drawn back, the Water will aſcend the Tube and fill the Lamb's Bladder, as *vid. Fig.* 15. *Tab. ſeq.*

THIS Ubiquity and Preſſure of Air is alſo viſible in a drinking Glaſs, which if you take and immerge it in Water, ſo that the Air can't get out, the Cavity will not be fill'd, the Air within hindering the Aſcent of the Water; which (as that learned Gentleman obſerves) may be ſhewn by putting of Paper into the Bottom of the Glaſs, which will not be wet; but if you ſet the Paper on fire, the Air will be ſo rarified, that the Water will riſe a good Way into the Glaſs.

UPON

Upon this Principle it is alſo, that diving Bells are made, by which Divers deſcend to the Bottom of the Sea, to fetch up Money or other valuable Goods that are loſt there, where they breath very freely under Water, and as I have been told, drink Punch and are very merry; but when it is about 33 Foot under Water, the Air will be compreſs'd to half the Space which it was before; and this ſometimes breaks their Blood-veſſels, and makes them bleed at Mouth, Noſe, and Eyes. And upon this Principle alſo Cupping is explain'd; the internal Air in the Blood rarifies, when the Preſſure of the external Air is taken away, and diſtends the Skin, and makes it ſwell in the Glaſs. This is a Proof ſays my oft quoted Author, whom I can never enough commend, that there is a great deal of Air in the Blood.

But to proceed to a farther Demonſtration of this Principle of Gravitation, the Barometer or Weather-glaſs is a more ample and clearer Proof of the Gravitation of Fluids one upon another, than any Inſtrument yet produc'd, in as much as thereby the Weight and Meaſure of them is found out.

This uſeful Inſtrument is, as ſome learned Men obſerve, ſo call'd from βάρος ſignifying Weight and μέτρον a Meaſure, (being as is elſewhere hinted) the Meaſure and Weight of Air; becauſe the Mercury or Quickſilver riſes and falls in Proportion in the Tube, as the Air is heavier or lighter, and ſo more or leſs preſſes the Quickſilver, that is in the Well, as they call it, of the Barometer; and thus far is agreed by all: But what it is that cauſes the Air to become ſometimes heavier and ſometimes lighter, is not ſo agreed.

But to proceed to the farther Explanation of this uſeful Inſtrument, it may not be amiſs to take a View of what the famous Jeſuit *Gobart* in a philoſophical Tract of his, concerning the Barometer Pag. 2. has ſet down concerning the Aſcent and Deſcent of Fluids, as it is in Queſtion 1. Pag. 2. wherein the Cauſe of the Aſcenſion and Deſcenſion of Mercury in the Barometer is very ſuccinctly handled, which I the rather give becauſe he was a Pleniſt, and maintain'd *that Nature does not admit of a Vacuum?* for ſays he, God Almighty has ſo diſpos'd of Nature, that where one Body deſerts any Place, another ſucceeds, and therefore Nature does not admit of a *Vacuum.*

In the next Place he ſays, *that Nature does not abhor a Vacuum,* becauſe ſhe can't abhor that which is not, and of which there can be no Danger; and in the next Place he ſays, that the Aſcent of Mercury and other Fluids does not ariſe from the

Dread

Dread or Fear of a *Vacuum;* for if Mercury was to riſe in a Tube from the Dread of that *Inane,* it would not ſtop at the Height of 30 or 40 Inches, but this Fear would urge it on, until it had driven it to 40 or 50 Foot high, and ſo on.

THE Barometer, this ingenious Gentleman chiefly recommends, is very much like that which *Ozanam* in his Hydroſtaticks gives a Deſcription of, which he calls Mr. *Hugen's* Barometer, which take as follows.

LET A B C be a glaſs Tube, hermetically ſeal'd at one of its Ends A, and open at its other End C, that as much Mercury may be pour'd into B, as will fill the Tube which reaches from the middle of the cylindrick Box E, to the middle of the other D, which muſt be 27 Inches diſtant from the firſt E; becauſe a Pillar of Air reaching from the Earth to the Top of the Atmoſphere or utmoſt Surface of the Air, will keep 27 or 28 Inches of Quickſilver in Equilibrio in a perpendicular Tube: Then fill C E the remaining Part of the Tube with any other Liquor, which will neither freeze in Winter nor diſſolve the Quickſilver, as ſuppoſe common Water mixt with one ſixth of *Aqua Fortis.*

WHEN the Mercury deſcends one Inch, (*per* Example) in the Box E, by the Gravity of the Air, it will riſe as high in the Box D, and the Water which is in the remaining Part of the Tube C E will deſcend in the Box E, and if (again) the Cavity of that Tube be 15 Times greater than that of the remaining Part of the Tube C E, 15 Inches of the Water of this narrow Tube, will be requir'd to take up the Height of one Inch in the Box; therefore as often as the Mercury riſes or falls one Inch, the Water will riſe or fall 15 Inches; and likewiſe when the Mercury riſes or falls one Line, the Water will fall 15 Lines; ſo that this Barometer ſhews the Alterations of the Air's Gravity 15 Times more ſenſibly than any common one. But D *Deſaguiliers* Pag. 140 of his Syſtem of experimental Philoſophy ſays, that " this Sort of Barometer has one Inconvenience, " which is, that as the Weather is hot or cold, ſo the Liquor " in the Tube C E will dilate or contract itſelf, and conſequently " riſe or fall; whereas the Mercury continues ſtill the ſame " Height. Since therefore the Mercury keeps always at the " ſame Height, however the Tube be inclin'd; the beſt Contri- " vance for a Barometer ſeems to be this, (*vid Fig.* 21. *Tab. ſeq.*) let A B C be a Tube bended as in the Figure, let B C " be about 26 Inches long, and A B ſo inclin'd, that it may be " 15 Inches; whereas A E ſhould not be above five according

D d to

" to the Structure; ſo for every Inch the Mercury riſes in the " Tube, it will riſe three in the inclin'd one A B.

Very much has been ſaid by Authors of the natural Effects of Air, in this remarkable Part of Nature; (the famous Jeſuit *Gobart* in Tract. Philoſoph. *de Barometro* Queſt. 2. Pag. 133. & *ſeq.* ſays) that this Aſcenſion and Deſcenſion of Mercury, is owing to the different Ponderoſity and Mutation of Air, but that that Mutation in Air can't come to paſs until other Changes ſhall go before, and which ſhall accompany, and be ſubſequent to that Mutation ; even as there can be no Expreſſion of Water out of Linnen, unleſs Water was therein before, with more to the ſame Purpoſe ; and then concludes *Pag.* 135. that 'tis a condenſative Cold, which is a poſitive concurrent Cauſe to the greater Weight of Air; and that the Expreſſion of Vapour is its Concomitant (only by the Accident *Condenſation*) for Serenity is a neceſſary Conſequent to that Condenſation and Expreſſion of Vapours ; for as the Generation of one, is the Diſſolution of the other; ſo from the Vapours which are ſo expreſs'd from Air, and (which are future Materials for Rain) follows that Serenity of Air, which is always conſequent to it.

In the laſt Chapter, I gave from Dr. *Deſaguiliers* a very ſhort and plain Account, of the Aſcent and Deſcent of Mercury in the Barometer &c. I ſhall finiſh what I began in that Chapter, from the Obſervations of our oft quoted learned Jeſuit abovemention'd, who concludes his Book with all the Obſervations and Objections which ſeem poſſible to be made on this great Phænomenon of Nature.

He lays it down as a Maxim in Hydroſtaticks, that Air may be either rarified or condens'd ; that by Rarefaction the Weight of Air is diminiſh'd, becauſe of the Multiplicity of Pores that are therein ; even as Pummice-ſtones, Sponges, or other opacous Bodies, are lighter than thoſe which are of a cloſer Contexture: He concludes therefore that condens'd Air preſſes and elevates the Mercury in the Tube, more than rarified Air does, becauſe by Condenſation, the Weight and Elaterium of the Air is encreas'd ; for condens'd Air is ſo conſtituted, that the ſuperior Parts act upon the inferior, by their Preſſure ; and that the Cauſe of the Acceſſion of ſuperior Particles, upon thoſe which are inferior, is a condenſative Cold ; and in another Place tells us, that Rarefaction which is caus'd by Heat, is that by which Air or any other Fluid extends itſelf from the Center towards the Circumference ; but Condenſation (which is a heavy Quality) cauſes

the Parts, of which it is compos'd, to recede from the Circumference to the Center.

Now theſe things being ſo, it is obvious (to common Obſervation) that the Air is heavieſt and exerts its lateral Preſſure on the Barometer moſt, when it is the moſt condens'd; he compares this elementary Sphere to a large Veſſel, which he ſuppoſes to be fill'd with Sponge, (explain'd by its own natural Dilatation) and on which Water is pour'd in ſuch a Manner, that there is no Part within the Veſſel where there is not Water and Sponge mixt together; by the Sponge he would repreſent common Air, the Earth, and other ſenſible Bodies; but by the Water the Æther or Atmoſphere, and as it is in the Veſſel which is every where fill'd with Water or Sponge; ſo it is in this elementary Sphere, there being in every ſenſible Place Air, or ſome other Body, and Æther alſo.

Now the Ponderoſity or Weight of this Air is encreas'd from divers Cauſes, one whereof is the * blowing of the North and North Weſt Winds, which are more condens'd by Cold than the other Winds are; and theſe Winds meeting with others that riſe from other Parts, at the ſame Time; gather together on a Heap, and mix with common rarified Air, and ſo encreaſe the Gravity of the Atmoſphere; and tho' there is not always the ſame Diſpoſition to Rain ſuppoſing the Air be rarified, becauſe in the Summer when the Earth is dry, it does not ſupply Vapours requiſite for ſuch Purpoſes; from whence (regularly ſpeaking) it does and ought to rain leſs at that Time than either in the Spring or Autumn: In the Winter alſo, whilſt the Earth, and a great Part of the Sea, is conſtring'd by Froſt; few Vapours being

* Not that I eſteem the hard blowing of any Winds to be the Occaſion of the Ponderoſity of the Air, but on the contrary, that it is thereby made the lighter, which is viſible by the Barometer in all high Winds, the Congregation of heavy Air together, is generally more leiſurely; for Air that is much agitated loſes of its direct Gravity, as is evident in a Charriot or other Carriage which is drawn on ſwiftly, where it is evident, that it cuts leſs into the Ground than if it was drawn ſlowly; for which take *Gobart* in his own Words. *Quia Aer multum agitatus multum perdit ſuæ Gravitationis, ſecundum Lineam rectam: Nam Ratione Agitationis, pondus tendit deorſum quidem, ſecundum Lineam rectam; ſed tendit etiam ſecundum obliquam; minus autem illud Corpus ponderat, quod oblique & directe ſimul tendit in Centrum ſuum; quia ſic dividitur aliquo modo pondus eo quod feratur recta & obliqua Linea in Centrum, ita dividitur ſuo modo illius Gravitatio: Illud evidens eſt in curru vehementer tracto; minus enim Terram premit in tali motu, quam ſilente traheretur. Vid* Tract. philoſoph. *de Barometro.* Dub. iv. pag. 178.

detach'd there from; neither has the Sun Heat enough to draw them to itſelf at that Time; yet in theſe Seaſons (different as they are) Rains often fall, the Winds abovemention'd wafting them from other Regions, where they were before generated, to the Place where by the Oppoſition of other Winds, they are forc'd to ſtop and fall down; ſo that Winds are both the Forerunners as well as concurrent Cauſes, of Rain and other Changes of Weather.

Last of all in the greateſt Heats of Summer whilſt the Dog-ſtar or Leo reigns (whilſt there are not Rains enough to nouriſh the Corn) there are obſerv'd, great Commotions of the Winds, frequent Thundrings and often great Showers, all which are foretold by the Barometer, even whilſt the Air is in that Diſpoſition; and the Reaſon why neither ſome contiguous Parts nor the whole Atmoſphere are not agitated or mov'd at the ſame Time is this, *(viz.)* for that the firſt Foot of Motion, in the Air, is reſiſted by the ſecond; which always encreaſes till it comes to the laſt Point, in which that Impetus deſiſts, which by how much the greater it is, by ſo much greater is the Agitation it makes in the Air, all which is nevertheleſs limited; for a Voice which is ſounded in the Air is heard but at a ſmall Diſtance; even ſo alſo a Cannon, on its firſt Exploſion, vehemently moves the neighbouring Air, and is yet nevertheleſs not heard above ten Leagues, except the Air be very ſtill; and unleſs it has ſome farther Helps, to make its Noiſe perceiv'd the farther; and this is the Reaſon why all Changes of Weather are circumſcrib'd to, and found in different Places.

From all which it is inferr'd, that from the Aſcent of Mercury is found out the Gravity of the Air; and this Knowledge may be ſaid to be directly and immediate; for as the Depreſſion of one Scale in any Ballance is known directly and immediately by the Riſe of the other, (becauſe they conſtitute one artificial Being) ſo in like Manner the Weight of Air and Mercury conſtitute or belong to one and the ſame thing, and the direct Cognition or Knowledge of the Elevation of one, is alſo the direct Knowledge of the Depreſſion of the other.

Many are the Scholiums with which this learned Author fills his Writings, concerning the direct and indirect, immediate and preciſe Changes of Air, which tend to no more than what (I have I think before laid down) that there can be no Change in Air unleſs there be ſuch a Ponderoſity preceding or going before it (as has been juſt now deſcrib'd) from whence

(he ſays) the Aſcent of Mercury ſhews indirectly, (that is, that the Condenſation of Air, the Expreſſion of Vapours, and the future Serenity of Weather, are not immediate or momentary) but neceſſary conſequents of this Change; but all theſe ſchool Definitions which are calculated rather to puzzle than inſtruct Mankind, I leave to the Diſcuſſion of thoſe who have more Leiſure than I have; and to ſum up all that can be ſaid on this Head, thoſe Vapours which fluctuate in the Air, and which are ſeen in or before wet foggy Weather, doe not encreaſe its Gravity; for when they are deſcending and hovering about the Earth (as they then are) 'tis then the Air is lighteſt and the Mercury in the Glaſs will riſe the leaſt, and when they are in the middle Region of the Air, they do not encreaſe its Gravity; for tho' the Air be heavier then, it is not becauſe the Clouds are high, but the Clouds are high, becauſe they are ſuſpended by Air which is heavy, as one Fluid which is heavy, is well known to ſuſtain another, which is lighter; for when the Air is more heavy than Vapours, they are forced to aſcend, till they meet with Air of the ſame ſpecifick Gravity of itſelf; and ſo continue to ſubſide till the Warmth or Rarefaction of the lower Air gives them Liberty to redeſcend; ſo that the Gravity of the Air conſiſts, in that which is condens'd and congregated together, as it is before all rainy falling Weather, which is what was to be prov'd.

A Thermometer is a long Tube of Glaſs ſeal'd hermetically, which has a ſmall Bubble at Top as O, and under it a long Neck as at B, which being fill'd about half Way with Spirit of Wine or any other Liquor that does not freeze in Winter (uſually ting'd of ſome Colour to diſtinguiſh it in the Tube) ſerves to ſhew the Degrees of Heat and Cold in the outward Air.

For this Purpoſe the whole Length of the Tube is divided into eight equal Parts, and thoſe eight into eight more, to have in all eight Times eight, which is 64 Degrees, to know more ſenſibly the Change which happens at any Time in the Temper of the Air, obſerving to what Degree the Water riſes that Hour of the Day, according as the Heat of the outward Air is encreas'd or diminiſh'd; for when the Air is hot, it cauſes the Air and Ball in the Tube A B to be rarified, and that Air being rarified expands itſelf and cauſes the Water to deſcend: And on the contrary, when the Air is cold it is condens'd, and gives Room to the Water to riſe, to which it muſt be added, that the ſmall End of this Thermometer be open, and immerg'd in an open Veſſel with the ſame Liquor with that which it contains.

The

The famous Monfieur *Gobart* in his philofophical Tract concerning the Barometer *&c.* fays, that the Thermometer has its Name from θερμὸν which fignifies Heat and μέτρον Meafure, and that it is made two Ways; the firft of Water, and the fecond of Spirits of Wine. A Thermometer which is made with Water is compos'd of two Parts, to wit, a Veffel and an oblong Tube with a Ball at Top, the extream Part of the open Tube muft be immerg'd in ftagnate Water, the Water being put into the Tube, it will afcend up to the Middle whilft the Cold encreafes, but will defcend whilft the Heat encreafes; a Sketch of which may be feen as I have taken it from *Gobart*'s drawing itfelf, and exprefs'd *Fig.* 15. *Tab feq.*

His Thermometer, which is made of Spirits of Wine, is made of one Glafs only, where the Ball is not at Top, but at the Bottom (as *vid. Fig.* 16. *Tab. feq.*) the Ball and above half the Tube are fill'd with Spirits, and the remaining Space is left for common Air; then it is hermetically feal'd, and in like Manner the Parts are noted upon the Frame, to which the Tube is faftned; and whilft the Heat increafes, the Spirits of Wine rife; but when it is inclinable to Cold they defcend. The Tube may be extended to three or four Foot high, the Divifions may be difcretionary according to the Length and Breadth of the Ball, the Tube may be denfer or thicker, but the Ball may be fmaller, from whence the Spirits will be more capable of Alteration.

The Barometer and Thermometer differ in the Ufes they are apply'd to; the Thermometer is us'd to know the Heat and Cold of the Air, but the Barometer to the knowing the Weight and Serenity of it; likewife the Water of the Thermometer afcends directly, but the Weight or Preffure of external Air indirectly, by the Contraction and Condenfation of that which is within.

With this Inftrument (ufeful as it is in all green Houfes and Stoves) may be compar'd the greateft Heat of one Summer with the greateft Heat of another, or the greateft Cold of one Winter with the greateft Cold of another; and from this you may know which of two Rooms is the hotteft, that being the hotteft where the Water will defcend the loweft in the Thermometer, the leaft Heat being able to rarify the Air contain'd in the Tube A B, as may be found by Experience; for if * the Hand be laid on the Ball A, its Heat will immediately rarify the Air and Caufe the

* Manus applicatus extremo Tubi aerem rarefacit, & illi condenfat fpiritus intra bullam, ---- applicatus bullæ fpiritus rarefacit, & illi per fuam dilatationem, et aerem comprimunt in fummo Tubi. Pag. 56. *Gobart* de Barometro.

Water

Water to deſcend, which will creep up gently into its Place again as ſoon as the Hand is remov'd, which will be more eaſily ſeen if you warm the Ball by breathing upon it.

I ſhall conclude this Account of hydroſtatick Inſtruments when I have obſerv'd, that 'tis by this Thermometer that you may keep your forcing Frames for Melons and other Fruits, to ſuch a due regular and temperate Heat as the Nature of your Plants require; as you may alſo the true State of Air neceſſary for the Preſervation of thoſe Exoticks which come from different Places beyond Sea, to which End I have, in the Houſe where I now live, a Thermometer, with the different Latitudes of the moſt remarkable Places of the World alphabetically digeſted, which may ſerve as a perfect Scale of Nature in the Direction of what Heat is proper for the Nouriſhment of every particular Kind of Plant, which ends what I have to ſay of the Thermometer.

And before I quit this Account of the Inſtruments by which the Principles of Hydroſtaticks are explain'd, it will not be improper for me to take Notice of the Hygrometer; a Specimen of which we have lately had in the Toy wherein the Man comes out of Doors in wet Weather and the Woman in dry.

This Hygrometer which is alſo call'd Hygroſcope, was as Monſieur *Gobart* Pag. 92. de Tract. philoſoph. de Barometro, tells us, not long ago invented by Father *Magnananus* of the Society of *Jeſus*; tho' there are others which give an Account of its being the Invention of an *Engliſhman*, the Uſe whereof is to find out preciſely the Humidity and Siccity of the Air: Let there be a Chord made of any muſical Inſtrument of Parchment, a Rope-ſtring or bearded Ear of Corn *&c.* the efficient Cauſes of which, are the Vapours of Water, which inſinuate themſelves into the Pores of all opacous Bodies, and becauſe they variouſly twiſt and ſwell the Fibres of other Bodies, ſo they cauſe various Motions therein, and the formal Cauſe is the Recontortion or Retwiſting of thoſe Fibres, ſituated in that various Habitude of Particles, to its firſt Poſition again, even ſo, that if a twiſted Chord be turn'd from the left to the right Hand in dry Weather, it will forthwith return from the right to the left in wet.

There are ſeveral Kinds, but the following one is in Eſteem; Make a Common Ballance as (A B *Fig.* 17. *Tab. ſeq.*) which muſt be ſuſpended by its Center of Motion G, and put into one of the Scales as D a Weight of Lead, and in the other Scale as C, a Piece of Sponge big enough to keep it in Equilibrio; then it will happen that when the Weather is moiſt, the Sponge grow-

ing

ing moiſt, by the ſucking in of thoſe Particles of Water that ſwim in the Air (which it will do more eaſily if it has been firſt dipp'd in ſalt Water;) for tho' the Water may be dried, yet thoſe ſaline Particles which are left behind will render it more ſuſceptible of the Moiſture of the Air) will become heavier than the Lead, and cauſe its Scale to preponderate, and alſo the Examen of the Ballance which is moveable about the fix'd Point G, to change its Poſition.

On the contrary, when the Sponge is dryed, by the Dryneſs of the Air, it will not be ſo heavy as the Lead, and conſequently riſe with its Scale, and make the Examen alſo to turn the other Way, and point to the Degrees of Dryneſs mark'd upon the Circumference of the Circle deſcrib'd about the Center of Motion G; but inſtead of an Examen and Circle, you may faſten the Scale C a little Chain made of ſeveral little Balls, which fall upon the horrizontal Plain as E F, and will lie upon it in greater number when the Moiſtneſs of the Air is greater; for in ſuch a Caſe the Scale C will deſcend lower, becauſe the Sponge being moiſter will conſequently be heavier.

Another Kind is thus made, let there be a Box divided into twelve Parts, and thoſe again into 20 ſmaller Diviſions (*vid Fig.* 22. *Tab. ſeq.*) in the middle of which let there be alſo put a Ear of Corn perfectly ripe, to which let there be fix'd a ſmall Index which may diſtinguiſh the Degrees on the Box by the Motion of the Ear of Corn. Concerning this Hygrometer divers things are noted; firſt of all, the Ear of Corn ſhould be mov'd from the Eaſt to the Weſt, through the Meridian in wet Weather, but in dry, from the Eaſt to the Weſt by the North Pole; the Reaſon of which is diſcoverable from the Structure of the Ear of Corn. In the next Place, if you ſet the Hygrometer near the Fire, the Blade of Corn will turn itſelf round and round as it were in Dances, either more or leſs according as it is nearer or farther off.

And to this Principle may be aſcrib'd the Interchanges the Man and Woman make in the new publiſh'd Toy beforemention'd, as whoever takes a little Notice may be more fully ſatisfied. There is another Method that † Monſieur *Gobart* takes in making this Hygrometer, the Draft of which I have taken from his Book *de Barometro* beforemention'd (*vid. Fig.* 23. *Tab. ſeq.*) tie

† Et per hos eoſdem Vapores multa hæc Oracula loquuntur & enarrant præſentem Aure Statum. Vid. *Gobart* Tract. philoſoph. *de Barometro* Pag. 98. & *ſeq.*

(ſays

(ſays he) a Rope to a Beam, in the extream Part of which, fix a Weight proportionable to the Rope, (that is) ſomething bigger, and the Weight ſhall be elevated in moiſt Weather and depreſs'd in dry.

If you deſire ſuch a thing in a ſmall Compaſs, you may uſe a Piece of Parchment, or the String of a Violin fix'd to the Wall; let the Globe or Ball be beneath, and let the Deſcription of the Degrees be made in Paper or Wood, and if there ſhould be deſcrib'd in a large Circle as at A, and on a pendulous Rope as at B, there will be a double Notation of that Motion (*viz.*) circular and perpendicular, and ſo both wet and dry may alſo be known.

The ſame is done by a Cat's Gut or other Piece of String nail'd acroſs any Part of a Wall, juſt in the Middle of the Degrees, but this String ſhould be dipp'd firſt of all, in ſalt Water, that it may be the more ſuſceptible of Moiſture, and may the ſooner retract or ſhrink up again. And our famous *Jeſuit* tells us, that every one unknowingly carries a Hygrometer about with him, if he will obſerve how his very Hair is let down, in moiſt Weather, but curl'd in dry; any Part made of Wood, as Doors, Windows, and ſuch like, ſwell in wet Weather, and ſhrink in dry, by the Inſinuation and Expreſſion of thoſe Vapours beforemention'd, and by thoſe very ſame Vapours it is, that thoſe dumb Oracles (if I may uſe *Gobart*'s own Words) ſpeak and tell the preſent State of the Air.

Having thus in Part given a rational and experimental Account to my Reader of the Inſtruments whereby the Principles of Hydroſtaticks are more fully explain'd, eſpecially in that of the Barometer, in which may be obſerv'd, one of the moſt wonderful Phænomena's in Nature; the Knowledge of which, as *Gobart* in his *Proœmium* or *Preface* to his *philoſophical Tract.* of the *Barometer*, is more difficult than the Flux and Reflux of the Sea; the Æſtus or Ebullition of the Sea (ſays he) owes its Motion to the Increaſe or Decreaſe of the Moon; but this may not improbably be attributed to a more potent Cauſe, and in this the Flux of the Barometer exceeds that of the Sea; becauſe nothing precedes nor follows that, but from this follow various things, as Rain, Snow, Hail, Wind, Tempeſts. Nor is it eaſy to know the Cauſe of this Aſcent or Deſcent, and what they portend, proves to be a laborious Enquiry. To follow our learned Author

This Inſtrument ſhews not only the preſent, but the future State of the Weather; by its Deſcent, is ſhewn Rain; and by its Aſcent Serenity of Weather; ſometimes it is ſerene after it

deſcends,

deſcends, and when it aſcends it is rainy; by its Aſcent is denoted Snow or Hail, by its Deſcent Winds and Tempeſts; *when the Mercury is elevated in a little Time, the following Serenity does not laſt long, and when it deſcends quickly, neither is the following Rain of any long Continuance; but when its Elevation is ſlowly, a more laſting Serenity; on the contrary, when it falls ſlowly, a conſtant Rain follows.* Oftentimes when it does not aſcend much it is ſerene, and when it deſcends but little it nevertheleſs rains much, all which is owing to the different Gravity or Diſpoſition of the Atmoſphere, in the various Seaſons and Turns of the Year.

The ſlower Aſcent of the Mercury, ſhews that a ſlow Condenſation and Depuration of the Air is made from the aqueous Vapours, that are therein; and ſo a ſlow Condenſation and Cleanſing of the Air is neceſſarily join'd with a longer, as the ſlower Aſſent of the Mercury ſhews a ſhorter Serenity following; for a ſlow Condenſation is the Cauſe, that all the Particles of Air are more interwove amongſt themſelves, and on the contrary, that the aqueous Particles neceſſarily expreſs themſelves the clearer by the longer Relaxation and Expreſſion of them; to be more plain, a notable Aſcent, and which ſhews the Serenity of Weather; (but that which is not laſting) is that when it riſes to a Finger's Breadth in a very little Time, to wit, in the Space of 12 or 15 Hours.

This Difference in the Riſe of the Mercury (as has been often Times noted) is from the different Gravitation of Weight of the Atmoſphere, for as *Gobart* Dub. 3. Pag. 161. *Mercurius multum ponderat, ergo debet dari magna mutatio in aere, ut ipſi æquiponderat:* And from this he ſays, that Mercury is to Air as fifty thouſand to one, as he collects from *Kircher.* For ſweet Water being to Air as 1000 is to 1; ſo Mercury is to Water as 15 is to 1, and conſequently that Mercury is to Air, as one is to 50 Millions; if therefore Mercury be rais'd to 40 Digits, that is to two Foot and a half, a Column of Air will be elevated above 37000 Foot.

Now as to the Height of the Atmoſphere I have to obſerve, that this Calculation of *Kircher*'s is apparently different to what others of later Date have made. Sweet Water is (by Dr. *Deſaguiliers* and others) reckon'd as 800 to 1, and the Difference between Mercury and Water is as 14 to 1, both which Sums being multiplied together make but 41200 (inſtead of the 50000 before ſet down by *Gobart* from *Kircher.*) Beſides, the different Degrees of the ſuperincumbent Weight of the Atmoſphere one

upon another, according to general Eſtimation is ſuch, that 'tis hard to aſſign any preciſe Height thereto, but it may be 4, 5, or 6 Miles more or leſs.

BECAUSE, I remember ſomewhere in the Hiſtory of *Hungary* to have read of a Mountain which was about 4 Miles high, to the Top of which ſome curious Obſervators aſcended, which Mountain was ſo high, as that they thought themſelves above the very Top of the whole Atmoſphere, all that was under them being heavy and blue, and that the View of the Earth below them was thereby intercepted *&c.* but that the Air where they were, was very ſubtle and ſerene; all which is a Demonſtration of the Uncertainty of this Height of the Atmoſphere, which has been the great Enquiry of many Ages. But to proceed with *Gobart*, from hence (ſays he) it may be eaſily collected how much the ſuperincumbent Air preſſes upon our Horizon, and how much that Mutation of Air (*quoad Pondus*) is, whilſt the Mercury is only elevated or depreſs'd to the fourth Part of a Finger, the Quantity of the elevated Mercury will give the requir'd Weight; from thence it may be gather'd, that it is not the protuberant Weight of the Column of Mercury only, which cauſes the Change of all the ſuperincumbent horizontal Air; and it ought to be wondred at, if that whole Mutation or Change of Air taken by Weight, (both fair Weather and Rain,) as well in Winter as in Summer may be deſcrib'd in the Compaſs of three Fingers, containing as it does the Viciſſitudes of tempeſtuous Air, Rains, variable and fair Weather, even as vaſt Regions may be deſcrib'd (in geographical Tables) in ſome ſmall Circle.

TO proceed, the Aſcent of Mercury from the Point of great Rains, to that of common or variable, is a Sign of ſerene or fair Weather, which is prov'd firſt from Experience, and ſecondly becauſe thereby the Vapours ſhall be fully ſqueez'd or preſs'd thereout, and the Condenſation be ſo ſufficient, that the Mercury muſt be carried up thither; and if you enquire why it could not aſcend higher, it is anſwer'd, that its Weight does not require it.

IT may indeed be from thence inferr'd, that the collateral Notes of the Barometer are ſuperfluous, becauſe it may be fair Weather, and yet neverthleſs the Mercury does or will ſtand ſtill, as well within the Limits of Rain or variable, as it would within the Limits of fair Weather; but this Inference or Allegation is deny'd, becauſe they who have chiefly obſerv'd the Aſcent and Deſcent of Mercury, have more frequently obſerv'd it to have rain'd, than to have been fair; and to have been tempeſtuous

rather than variable,, when it has come to the Mark of ferene or rainy Air. And what has happened commodioufly enough to thofe who have made Obfervations concerning the Barometer, will not happen fo well to thofe who are unwilling to know the Caufes and Effects of that Afcent and Defcent.

ANOTHER Objection brought againft the Barometer is that the fame Air according to all Circumftances cannot caufe both fair Weather and Rain, to which it is anfwer'd, that it may ponderate in the fame Manner, altho' it be join'd fometimes with Rain and fometimes with fair Weather; for Mercury might ftand above fair Weather and yet be join'd with Rain, becaufe Vapours which have been mix'd with Air already condens'd, can never lofe its Elaterium, becaufe of its Condenfation; and therefore tho' the Mercury might ftand the higher, it might neverthelefs rain, and that for the following Reafons.

FIRST, for that Air is fubject to various Alterations which take their Rife (as I think I have before hinted at) from the thick Vapours of the Water, from the Exhalations of the Earth, and from the Effluviums of terreftrial Bodies, whether animate or inanimate, from Heat or Cold, or from Rarefaction and Condenfation.

Secondly, Thefe Vapours and Effluvia's are fuftain'd in the Air, as Particles of a lighter Kind are fuftain'd, by thofe which are heavier in Water; the Reafon of which is (as before) for that the Liquidity or Cohæfion of the implex'd Particles of which they are compos'd, are like Nets whofe exterior Parts they faften to the Lattice of a Window, as they may do from the different Caufes, from which that Mixture is made; not only in the Bottom, but alfo in the fuperior and middle Parts, as is plain in Water, on which falt Water is generally put.

Thirdly, It may come to pafs that one Species of Particles may over-top at one Time, which Particles may be over-top'd by others at another; for the Air is fometimes fo full of Vapours, that the whole may feem as if it was Water, which either infinuate themfelves into Bodies which are very porous, or ftick to the outer Parts of denfer and more polifh'd Bodies, even as Marbles which are fometimes feen to diftil, as it were Drops of Water, and which neverthelefs are as fo many igneous or fiery Particles mix'd with Vapours, which in rainy Weather are warm, and which are neverthelefs cold, when it is not fo; or when they are overcome by nitrous Particles, or by others which ferve for the Formation of Hail or Snow.

Fourthly, That the diſperſt Particles of Water, don't make that which is ſenſibly ſo, (unleſs they are gather'd together) is evident in a Looking-glaſs; for the Air which we breath has Particles of Water mix'd therewith, which however does not make ſenſible or real Water, unleſs the Glaſs, where they are gather'd together, be mov'd nearer to the Mouth; for which Reaſon it is neceſſary thus to expreſs it when we ſpeak of igneous Particles, which do not make a ſenſible or real Fire in the Air, unleſs when gather'd together in one Body, from whence they break out into Lightening, Thunder and the like.

Fifthly, Air may be ſometimes full of Vapours, and ſometimes deſtitute of them: The Air is fill'd by their Inſinuation, and evacuated by their Agitation or Preſſion, even as a Net grows dry through Agitation, or a Sponge or wet Cloth by Preſſion; Air alſo may be fill'd or clear'd of Vapours, ſometimes ſlowly and ſometimes quickly; when the Air is clear'd of Vapours ſlowly, it recovers its Elaterium and Weight ſlowly again, but when it is clear'd quickly it ſoon recovers its loſt Particles; from all which follows the ſlow or precipitate Riſe of the Mercury, which comes to paſs immediately after the Air has recover'd its Weight, but more ſlowly from its Condenſation.

Sixthly, It muſt be obſerv'd, that when more igneous than aqueous Particles abound in the Air, the Effect of Fire follows, which overcomes the Activity of the other Agent of Water, from whence the Heat and Rarefaction of the Air follows alſo. And when the Particles of Water ſuperabound, then cold and condens'd Air follows. And if Heat and Cold be equally join'd in one Foot of Air (as is I think elſewhere hinted at) it will ſo temper their Influxes, and in a ſtated certain Time will conſtitute ſuch an Air, that from thence will follow a moderate Elevation of the Mercury, which will be chang'd again by the Occaſion of other Particles, either of Water or Fire. And truly here is diſcover'd the various Combination of theſe Particles, as well to the Elevation as Depreſſion of the Mercury; neither does any certain Tempeſt add any thing of itſelf to the *Elaterium* or Weight of the Air, but on the contrary clears it.

For firſt of all the Weight of the Air is equal both in Winter and Summer, becauſe in the Winter, a condenſing Cold prevails; and in the Summer, the Material of new Air, which is continually elevated by the Sun, (even as the Smoak which we ſee in a ſerene Sky, which we ſee drawn by the Heat of the Sun from dry Ground) is nothing elſe but that new Material for Air which I have been juſt now deſcribing.

From

From whence it may be gather'd, that the Weight of Air may be equal, whether the Air be ſerene or rainy; if it rains, a condenſing Cold may from ſome other Cauſe abound, if ſerene and fair a rarifying Heat; ſo alſo there may be a greater Weight of Air when there are Clouds, and leſſer when there are none; if the Winds blow it will weigh leſs, if the Clouds are high and the Air is quiet, it will gravitate more, becauſe (as has been before obſerv'd) when there is a greater Quantity of Air below than there is above, the ſuperior Clouds do not exert their Elaterium or ſpring ſo much as when there is a leſſer.

In the ſecond Place, Air may be condens'd in Summer as well as Winter, by reaſon of thoſe cold Particles which are brought by the Force of North Winds into thoſe Parts, and indeed in ſuch a Plenty, that they may not only hinder the Rarefaction of the Air, but condenſe it in the ſame Manner as it us'd to be condens'd in the Winter; and this I have been told ſometimes happens even in *Spain* and other warm Regions, where the Colds ruſh down from the Mountains with ſo great a Violence, (being there lodg'd by the northern Winds) that it ſtrikes the Inhabitants as it were dead and benumb'd at once. In like Manner Air may be rarified by Heat as well in Winter as Summer, becauſe ſuch a Number of warm Spirits may be ſent from the South, as may render the Air more warm, from which neceſſarily follows the Loſs of Air's Equiponderacy, and conſequently the Deſcent of the Mercury.

And thus have I from *Gobart*, and other learned Authors, endeavour'd to ſtate the Reaſons, of the different Gravities of the Air; at different Seaſons and Times, the greateſt whereof is indeed from Air congregated and blown together by the blowing of Winds againſt Hills or Mountains, or by meeting and claſhing with Air of the ſame or like Nature.

I ſhall but juſt anſwer one or two Objections more before I draw towards a Concluſion of this Chapter.

It has been objected by the Enemies to the Barometer, that the ſlow Aſcent of the Mercury, adds nothing to the future Serenity of the Weather; becauſe by Obſervation it has appear'd to riſe, and yet the third Day it rain'd; the Truth of which Fact is allow'd, for that two Days were not ſufficient for the Purgation of the Air, more Time being required for the drying of Linnen much moiſtned with Water, than that which is tinctur'd by a ſmall ſprinkling only. Air dry'd, and compreſs'd as it were of all its Parts, requires a moiſt Sky for many Days, (becauſe

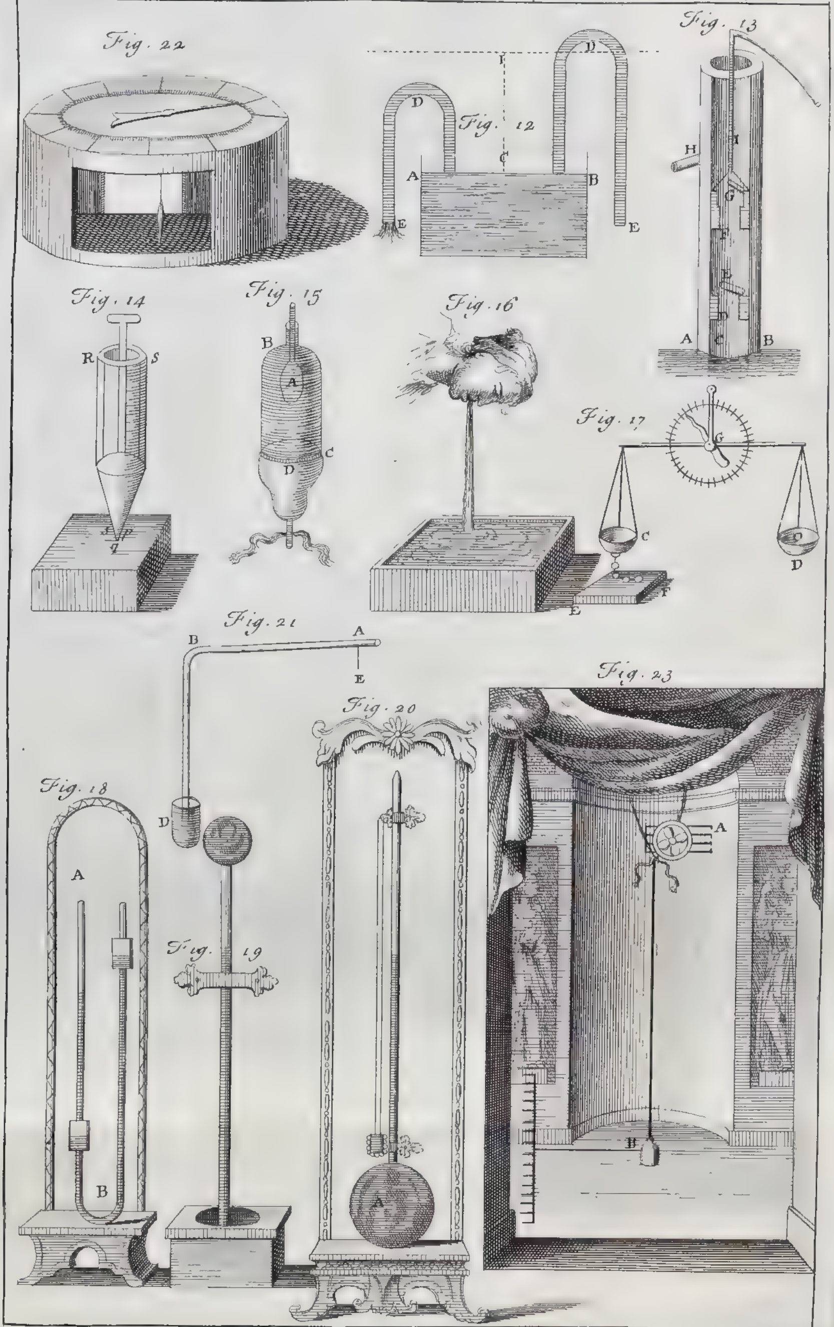


Fig. 22
Fig. 12
A
B
C
D
E
I
Fig. 13
A
B
C
D
E
F
G
H
I
Fig. 14
R
S
p
q
Fig. 15
A
B
C
D
Fig. 16
Fig. 17
C
D
E
F
G
Fig. 21
A
B
D
E
Fig. 20
A
Fig. 23
A
B
Fig. 18
A
B
Fig. 19

Toms Sculp.

" bles, as poffible, fhould be left in the Mercury. Then the " Tube, being ftop'd with the Finger, and inverted, was open'd " into a long, flender, cylindrical Box, half fill'd with Quickfil- " ver; when that in the Tube fubfiding, and a Piece of Paper " being pafted level to its upper Surface, the Box and Tube " were, by Strings, carefully let down into the Receiver; and " the Cover, by means of this Hole, flipt along as much of the " Tube, as reach'd above the Top of the Receiver: The Inter- " val left betwixt the Sides of the Hole, and thofe of the Tube, " being exquifitely fill'd up with melted Diachylon; and the " round Chink, betwixt the Cover and the Receiver, were likewife, " very carefully clos'd; upon which Clofure, there appear'd no " Change in the Height of the mercurial Cylinder; whence the " Air feems to bear upon the Mercury, rather by Virtue of its " Spring, than of its Weight; fince its Weight could not be fup- " pos'd to amount to above two or three Ounces; which is in- " confiderable, in Comparifon of fuch a Cylinder of Mercury " as it would fuftain. Now the Sucker was drawn down, and " immediately, upon the Evacuation of a Cylinder of Air, out " of the Receiver, the Quickfilver in the Tube fubfided; and " Notice being carefully taken of the Place where it ftop'd, we " work'd the Pump again, and mark'd how low the Quickfilver " fell at the fecond Exfuction: But, continuing thus, we were foon " hinder'd from accurately marking the Stages in its Defcent, " becaufe it prefently funk below the Top of the Receiver: So " that we could, from hence, only mark it by the Eye. And " continuing pumping, for about a quarter of an Hour, we could " not bring the Quickfilver, in the Tube, totally to fubfide. Then " we let in fome Air; upon which, the Mercury began to re- " afcend in the Tube, and continued mounting, till having re- " turn'd the Key, it immediately refted at the Height it had then " attain'd. And fo, by turning, and returning the Key, we did, " feveral Times, impel it upwards, and check its Afcent; till, " at Length, admitting as much of the external Air, as would " come in, the Quickfilver was impell'd up, almoft, to its firft " Height; which it could not fully regain, becaufe fome little Par- " ticles of Air were lodg'd among thofe of the Quickfilver, and " rofe in Bubbles to the Top of the Tube.

" It is remarkable, that having, two or three Times, try'd this " Experiment, in a fmall Veffel; upon the very firft Cylinder of " Air that was drawn out of the Receiver, the Mercury fell, in

" the

" the Tube, 18 Inches and a half; and, at another Time, 19
" Inches and a half.

" WE, likewiſe, made the Experiment in a Tube leſs than two " Feet in Length; and, when there was ſo much Air drawn out " of the Receiver, that the remaining Part could not counter- " balance the mercurial Cylinder, it fell above a Span at the " firſt Stroke; and the external Air being let in, impell'd it up " again, almoſt to the Top of the Tube: So little matters it, " how heavy or light the Cylinder of Quickſilver be, provided its " Gravity overpower the Preſſure of as much external Air, as " bears upon the Surface of that Mercury into which it is to " fall.

" LASTLY, we obſerv'd, that if more Air were impell'd up, " by the Pump, into the Receiver, after the Quickſilver had re- " gain'd its uſual Standard in the Tube, it would aſcend ſtill " higher; and immediately, upon letting out that Air, fall again " to the Height it reſted at before.

" BUT, in order to fill the *Torricellian* Tube with Exactneſs, " the Edges of the open End ſhould be made even, and turned " inwards, that ſo the Orifice, not much exceeding a quarter of " an Inch in Diameter, may be the more eaſily, and exactly ſtop'd " by the Finger; between which, and the Quickſilver, that there " may be no Air intercepted, it is requiſite that the Tube be " perfectly full, that the Finger, preſſing upon the protuberant " Mercury, may rather throw ſome out, than not find enough to " keep out the Air exactly. It is, alſo, an uſeful Way, not quite " to fill the Tube, but to leave, near the Top, about a quar- " ter of an Inch empty: For, if you then ſtop the open End, " and invert the Tube, that quarter of an Inch of Air, will " aſcend in a great Bubble to the Top; and, in its Paſſage, lick " up all the little Bubbles, and unite them with itſelf, into one " great one. So that, if by re-inverting the Tube, you let that " Bubble return to the open End of it, you will have a much " cloſer mercurial Cylinder than before, and need add but a very " little Quickſilver more, to fill up the Tube exactly. And, " laſtly, as for ſuch little and inviſible Parcels of Air, which can- " not be thus gather'd up, you may endeavour, before you in- " vert the Tube, to free the Quickſilver from them, by ſhaking " the Glaſs, and gently knocking on the Outſide of it, after every " little Parcel of Quickſilver is pour'd in; and afterwards, forcing " the Bubbles to diſcloſe themſelves, and break, by applying a " hot Iron near the Top of the Glaſs; which will raiſe the Bub-

" bles ſo powerfully, as to make the Mercury appear to boil. " I remember, that by carefully filling a ſhort Tube, tho' not " quite free from Air, we have made the mercurial Cylinder " reach to thirty Inches, and above an Eighth; which is men- " tion'd, becauſe we have found, by Experience, that in ſhort " Tubes, a little Air is more prejudicial to the Experiment, than " in long ones.

" We fill'd a glaſs Tube, about three Feet long, with Mer- " cury; and having inverted it into a Veſſel of other Quickſilver, " that in the Tube fell down to its uſual Height; leaving ſome " little Particles of Air in the Space it had deſerted: For, by the " Application of hot Bodies, to the upper Part of the Tube, the " Quickſilver would be a little depreſs'd. Laſtly, having put both " the Tube, and the Veſſel whereon it reſted, into a conveni- " ent wooden Frame, we placed them together in a Window of " my Chamber.

" And during ſeveral Weeks, that the Tube continu'd there, " I obſerv'd, that the Quickſilver did ſometimes faintly imitate " the Liquor of a Thermometer; ſubſiding a little in warm, and " riſing a little in cold Weather; which we aſcrib'd to the greater, " or leſſer Preſſure of that little Air, which remain'd at the " Top of the Tube, expanded, or condens'd by the Heat, or " Cold of the ambient Air. But, the Quickſilver often roſe, and " fell in the Tube very conſiderably, after a Manner, quite con- " trary to that of Weather-glaſſes, where Air is at the Top; for " ſometimes, I obſerv'd it, in very cold Weather, to ſink much " lower, than at other Times, when the Air was comparatively " warmer. And ſometimes, the Quickſilver would, for ſeveral " Days together, reſt almoſt at the ſame Height; and at others, " it would in the Compaſs of the ſame Day conſiderably vary " its Altitude, tho' there appear'd no Change, either in the " Air abroad, or in the Temper of that within my Room, nor " in any thing elſe, to which ſuch a Change could reaſonably be " imputed; eſpecially conſidering, that the Space wherein the " Mercury continued unſettled for five Weeks, amounted to full " two Inches; deſcending in that Time about $\frac{9}{16}$ of an Inch from " the Place where it firſt ſettled, and aſcending the other Inch, " and $\frac{7}{16}$; and when we took the Tube out of the Frame, after it " had ſtaid there part of *November*, and *December*, a large Fire " being then in the Room, we found the mercurial Cylinder to " be above the upper Surface of the ſtagnant Mercury 29 " $\frac{3}{4}$ Inches.

" Such an Inequality in the Riſe, and Fall of the Mercury
" will, I fear, render it difficult to determine by the Barometer,
" whether the Moon be the Cauſe of the Tides, eſpecially, till
" the Reaſon of this odd Phænomenon be certainly known; which
" ſeems principally to depend upon conſiderable Alterations in the
" Air, in Point of Rarity and Denſity,

" 19. We took a Tube of Glaſs, about four Feet in Length,
" hermetically ſeal'd at one End, fill'd it with common Water,
" and inverted the open End, beneath the Surface of a Veſſel of
" Water. Then this Veſſel, with the Tube in it, being let down
" into the Receiver, the Pump was ſet on work; when, till the
" Receiver was moderately exhauſted, the Tube continu'd quite
" full of Water; it being requiſite, that a great Part of the Air
" contain'd in the Receiver ſhould be drawn out, to bring the
" remaining to an Equilibrium, with ſo ſhort a Cylinder of Wa-
" ter. But, when once the Water began to fall in the Tube,
" each Exſuction of Air made it deſcend a little lower; tho' no-
" thing near ſo much, nor ſo unequally, as the Quickſilver did.
" The loweſt, we were able to draw down the Water, was, to
" about a Foot above the Surface of that in the Veſſel. And,
" when the Water was drawn down thus low, we found, that
" by letting in the outward Air, it might be immediately im-
" pell'd up again, to the higher Parts of the Tube.

" Upon making this Experiment in a ſmall Receiver, we ob-
" ſerv'd, that at the firſt Exſuction of the Air, the Water uſually
" ſubſided ſeveral Inches; and at the ſecond, ſometimes near two
" Feet; whereupon letting in the external Air, the Water was
" impell'd up, with a very great Velocity."

The ſame learned Author Pag. 453. of his Pneumatics, that from the Computation of the Weight of Air to Water, it might be expected ſhould be decided the great Controverſy about the Height of the Atmoſphere *&c.*"

To conclude this Chapter with the learned Dr. *Clarke* in his Notes on *Rohault* and in *Philoſoph. Tranſac.* No. 181. 292. this Difference which is obſerv'd in the Gravity of the Atmoſphere (let its Height be what it will) the Reaſon (ſays he) why the Quickſilver in the Barometer ſhould ſtand lower, when the Air is thick, dry and clear; and laſtly the Barometer varies leaſt between the Tropics, becauſe the Wind is there almoſt always gentle, and blows the ſame Way. And thus much of the Knowledge of Hydroſtaticks from the Barometer and other Inſtruments.

BOOK. II.

CHAP. XVI.

Of Air *and its Effects in* Hydroſtaticks, *by its Elaſticity: As alſo of its Dilatation and Compreſſion.*

ELASTICITY, as defin'd by *Wallis (Cap.* 13. *Def.* 1. of his *Mechanicks)* is that Body, which, being thruſt by Force out of its own proper Place, endeavours to reſtore it ſelf again to its primitive Form and Figure, and that *vis elaſtica* has its Derivation *ab* ἐλαύνω, *agito, abigo, excutio, expello;* and that ἐλάτηρ is of the ſame Original; which *elater* ſignifies in our Language *a Spring,* from the ſame Root that *Salire or Exſilire* ſignifies in the *German* and *Daniſh* Languages, *Springen* or *Springhen;* and from thence a ſpringy Body is call'd *Corpus Elaſticum,* an elaſtick Body; and a Body thus elated is ſaid to be endued *(vi elaſticâ)* with an Elaſticity or Springineſs.

It ſignifies alſo, and perhaps more frequently in a metaphorical Senſe, *germinare,* even as Buds (*exſiliant*) that is, bud or ſpring out of a Tree; and from thence *vernum* is called Spring, becauſe 'tis chiefly then that all things put forth: For this Reaſon alſo a Fountain or ſmall Rivulet is call'd *aqua ſaliens,* a *Spring, ob ſalientem aquam,* as *Wallis* defines it; it is called *exſilire* alſo from the Springing of a Mine, as that learned Author will have it.

But to proceed, As a ſoft Body is that which when preſs'd yields to the Stroke, and loſes its former Figure, and cannot recover itſelf; ſo an elaſtick Body is that which tho' it yields for a while to the Stroke, yet can afterwards recover its former Figure, by its own natural Power; and if it can do this with the ſame Force, as that which preſs'd upon it, we ſay it is perfectly elaſtical.

Some of Note there are, which allow little or no Elaſticity to any thing, but Air, and *Marriotte* himſelf, Pag. 68, of his *Hydroſtaticks*, as tranſlated by Dr. *Deſaguiliers*, ſays that Water has no ſenſible Elaſticity, and makes (as is elſewhere obſerved) an *equilibrium* with other Bodies only, by its own Weight or Impulſe: But the laborious *Harris* (in his *Lexicon Technicum, ſub titulo E.)* ſays, If there were no ſuch thing, or if in other Words this Elaſticity was not almoſt general, the Laws of Motion found out by Mathematicians (who, heretofore I add, knew little of Hydroſtaticks) about the Percuſſion of Bodies, would hold univerſally, and be without Exception true, and the Body (as Mr. *Keil* in his Introduction *ad veram Phyſicam*, Pag. 151) would move jointly that Way towards which the ſtronger Body tended before the Shock or Percuſſion, and with a Celerity eaſily determinable by the Laws of Motion.

But becauſe there are few Bodies (many of which are condens'd and hardiſh) without ſome Degrees of Elaſticity, even ſoft Clay, Wax, caſt Lead, &c. according to *Wallis*, containing in them ſome Particles of elaſtick Matter: From hence it is (I ſay) that Bodies which ſtrike or move againſt one another, do ſpring, recede, or leap back, and move with different Degrees of Velocity, ſometimes one Way, or ſometimes according to the Direction of the Line, or the different Degrees of Velocity or Strength in the Percutient or Weight of the Body percuſs'd or ſtruck againſt.

If you imagine (ſays a curious Author on this Subject) a String or Wire to be ſtrain'd or faſtned firm at each End; then 'tis plain, that if the middle Part of the String, or any other, be drawn by the Hand, or preſs'd by a Weight out of that right Poſition in which it was at firſt, that if the Force which moved it, be not greater than the elaſtick Force of the String, the String will fly back again; and if the Weight or Body be not removed, it will drive it before it, as the String of a Croſs-bow doth an Arrow or a Bullet, and the acquired Velocity of the String will carry it beyond its firſt right Poſition towards the oppoſite Parts, and that ſo far as till the Motion that Way be equal to the Elaſticity of the String; and then being quite deſtroy'd, the String will return again as before: And thus ſpringing forwards and backwards, would (abſtracted from the Reſiſtance of the *Medium*) like a double Pendulum, make continual Vibrations.

Thus alſo, if you ſuppoſe any Weight to fall on an immovable, fix'd, and perfectly elaſtick Body; on the Contact of each with the other, the Parts of the elaſtick Body will ſpring back, or recede inwards, till the elaſtick Force be rais'd up equal to the Momentum

of

of the falling Body, and then this latter, ceafing its elaftick Force, will caft the Body upwards, or from it, as was impell'd againft it, recovering its former Figure again; but if both the Bodies being elaftick, neither of them being fix'd or movable, then the elaftick Force will act equally in each Body, and produce equal Mutations of Motion.

THE ufual Methods of judging whether Bodies are endued with this elaftick Quality or not, is to enquire, whether, on being ftruck, they give any *Tinnitus* or ringing Sound, or indeed any fenfible Noife; for if they do, you may in fome meafure conclude them to be elaftical, and that they are fo in Proportion to the Strength and Acutenefs of the Sound they emit: And *Wallis*, *Cap.* 13. *Prop.* 1. *Pag.* 692. of his *Mechanicks* aforefaid, doubts not but there is an elaftick Quality even in Marble, Wood, Earthen Ware, hard Metals, and in innumerable other things, which is difcoverable not only by the Sound, but is eafily obferv'd both by Infpection and Touch, from that Shaking and Trembling it is fo notably endued withal.

THE curious and inquifitive Mechanick and Philofopher *Gobart* fays, *(a)* That Elafticity is caus'd from the innate Inclination of its Parts, endeavouring to obtain a larger Space for themfelves. But to draw towards an End, and to conclude this preliminary Difcourfe of Elafticity, let us fum it up with the well knowing *Wallis*, who, in his *Definitions*, *Cap.* 13. fays, That from whence, or however fituated this Elafticity in Bodies is, he does not pretend to enquire, nor could the Nature of it be explain'd fo well as to fatisfy either the Reader or himfelf in it. It is fufficient, that there is fuch a thing in Nature, that when it is prefs'd, it will return and rife again; but how this Body is reftor'd (efpecially in Air) to its former Pofition, no body can perfectly difcover: But to make the ftricteft Enquiry we can of this Force, interfper'd as it is thro' the whole Compafs of Nature, let us in the next place take a View, contain'd as it is, under the general Denominations of Elation, or fpringing forwards, and of Refilition or Reflection, the reflecting or leaping back of Bodies one from another; to which may be preliminarily fet down what relates to the Explanation of Rarefaction, Dilatation, Extenfion, or the Condenfation or Expanfion of Air.

Gobart tells us *(Par.* 1. *Pag.* 102. *Prædict.)* That Rarefaction is not to be confounded with Dilatation, nor Dilatation with Elafticity;

(*a*) Elafticitas fit ab innatâ inclinatione partium conantium ex fe majorem locum obtinere (vid. Par. 1. Pag. 102. *of his* Tractat. Philofoph de Barometro.)

city ; the laſt Word is already enlarged upon, as endeavouring to obtain larger Room for the Motion of its Parts, Dilatation extrinſick, ſo as that the Order of its Parts cannot be ſeparated, but Rarefaction is compos'd in this, that thereby the Order of its Parts may be chang'd, and that the Parts of which it is compos'd ; may be ſeparated one from another : On this Account it is, that Rarefaction is made by the Means of intromitted Heat; but Dilatation by the Means of extrinſick Traction, or the Intromiſſion of another Body ; but Elaſticity by ſome intrinſick Means, whereby one Particle of Matter acts againſt another of its own Accord; but Extenſion, in the Order of which it is ſaid that a Body is rarified, is that which belongs to that Body the Moment of its Production.

Nor are theſe Definitions (eſpecially of Air) idle Speculations only, but real and effective Truths, and ſuch, by which ſome of the greateſt Phænomenas in Nature are demonſtrated and explain'd, and which is eſpecially of the greateſt Uſe in Hydroſtaticks.

To proceed to Fact; Air (as our ingenuous Author has it) has a Property greater than other Liquids ; that is, that it can take up a greater or a leſſer Space, according as it it compreſs'd with a different Force; and as ſoon as that Force is diminiſh'd, it expands it ſelf again, and by Reaſon of this Analogy of the Effects of Air with other Bodies it is call'd elaſtick.

That Air may be compreſs'd, appears from what the oft-quoted *Boyle*, *Wallis*, and other Authors have ſaid of extenſive Solidity, Vacuity, *&c.* particularly in the Experiment of a Syringe, ſo cloſe ſhut up at the End of it, that it will reſiſt the Piſton ſo, as that you can't thruſt it to the Bottom with all the Force you have, unleſs you break your Machine. That Air may be dilated, will appear from the following Experiment made uſe of by *Graveſande* and others, (*Fig.* 5. *Tab. Seq. Exper.* 1.) Take the Tube A B cloſe at the End A, and pour Mercury into it, ſo that there may be ſome Air left in the Tube, which when in the State of the external Air, will take up the Space A C, if the End B of the Tube be immers'd into Mercury in a Veſſel, the Mercury in the Tube will deſcend to *g*, and there remain. The Height *i g* differs very much from the Height of the Mercury in the firſt Experiment of the aforegoing Chapter (concerning the Gravity of Air) which does not ariſe from the Gravity of the Air in the Tube ; for its Weight is too little to produce any ſenſible Difference in the Height of the Mercury : The Expanſion of the Air cauſes this Effect ; and from this Experiment may be deduc'd this Rule, that the Air dilates it

ſelf

ſelf in ſuch a Manner, that the Space taken up by it is always inverſely, as the Force by which it is compreſs'd.

(To proceed) the Compreſſion by which the common or external Air is compreſs'd, is the Weight of the whole Atmoſphere, which is equal to a Pillar of Mercury of the Height, *h f*, *Fig.* 1. Therefore the Compreſſive Force may be expreſs'd by that Height; the Space taken up by the Air in the Tube where it is compreſs'd by ſuch a Force is A C.

But in the laſt Experiment the Preſſure of the Atmoſphere exerts two Effects; it ſuſtains the Pillar of Mercury *i g*, and it reduces the Air in the Tube to the Space *g* A; if the Force *g i* be ſubſtracted from the Preſſure of the whole Atmoſphere; that is, if the Height *g i* be taken from the Height *h f* (*Fig.* 1.) there remains the Force by which the Air is compreſs'd in the upper Part of the Tube; but this Difference of the Heights of the Mercury *h f* and *g i* is always to *h f* as A C to A *g*; that is, their Forces are inverſely as the Spaces; and this Rule holds good alſo in compreſs'd Air.

Experiment 2. (*Fig.* 6. *Tab. Seq.*) Take a Curve Tube A B C D open at A, and ſhut at D; let the Part B C be filled with Mercury, ſo that the Part C D may contain Air of the ſame State or Tenour as the external Air; therefore the compreſſing Force is the Column of Mercury, whoſe Height is *h f*, *Fig.* 1. and by this Height muſt this Force be expreſs'd, as in the foregoing Experiment; let the Space taken up by the Air be C D; pour Mercury into the Tube A. B. that it may riſe up to *g*; the Air will be reduc'd to the Space *e* D: Now the compreſſing Force acts as ſtrongly as a Column of Mercury of the Height *f g*, and alſo the Preſſure of the external Air upon the Surface *g* of the Mercury; this Force is expreſs'd by the Heights *f g* in this Figure, and *h f* in *Fig.* 1. and this Sum is always to *h f* (*Fig.* 5.) as C D to *c* D; and again the Forces are inverſly as the Spaces.

The Elaſticity of Air is alſo as its Denſity; for the laſt is inverſly as the Space taken up by the Air; therefore the Force compreſſing the Air, is equal to that by which the Air endeavours to expand it ſelf; and this Force is its Elaſticity: And hence it follows, that the Air in which we live is reduc'd to the Denſity which it has near the Earth, by the Preſſure of the ſuperincumbent Air, and that it is more or leſs compreſs'd, according to the greater or leſſer Weight of the Atmoſphere; for which Reaſon alſo the Air is leſs denſe at the Top of a Mountain, than at the Foot of it, as being compreſs'd by a leſs Weight; that is, in

when you are at the Top of the Mountain; for as you are nearer the Top of the Mountain, you conſequently have leſs Weight lying upon you, a Column of Mercury, (as has been before obſerv'd) of 29 Inches high below a Hill, being of equal Weight with the Preſſure of the Atmoſphere, and a Pillar of Water of thirty two Foot equal thereto; but if you carry a Tube of Mercury to the Top of a Hill 100 Foot high, the Mercury will deſcend a Quarter of an Inch.—— Which proves that the lower Air is elaſtick, or expands it ſelf according to its Denſity.

How far this Property of expanding it ſelf is or may be extended, is not certainly known, notwithſtanding the curious Experiments that have been made to find it out; and it is very probable that it cannot be determin'd by any Experiments: Nevertheleſs, (as a learned Author has it) if you compare the following Experiment with the Experiment of the Air compreſs'd in a Pump, it will appear that the Air may take up 20000 Times more Space in one Caſe than in the other.

(Experiment 3. *Fig.* 7. and *Tab. Seq.*) Let the Glaſs A B about fourteen Inches high be exactly fill'd with Water, having a Braſs Cap fix'd to the End of it at B, by which it is to be ſcrewed to the Pump, that is before mention'd, (*vid. Fig.* 6.) by drawing out the Piſton of the Pump, the Water deſcends into it by its Gravity; and the Place in the upper Part of the Veſſel is void both of Air and Water; the Air Bubbles in the Water which are now compreſs'd, becauſe the Air does not act upon the Surface of the Water, expand themſelves, and riſe up to the Surface of the Water; in that Motion the Bubbles are accelerated, ſo as not to be ſeen diſtinctly near the Surface; upon Account of their very ſwift Motion, they alſo grow bigger, as they aſcend; and if you compare the Diameter of a Bubble at B with its Diameter, when it is come almoſt up to the Surface of the Water, or ſo far as it may be ſeen diſtinctly, its Diameter is at leaſt four Times as great as before.

The upper Part of the Glaſs, as was ſaid before, is intirely void of Air, for the ſmall Quantity of Air, which is continually going out of the Water is not to be taken Notice of here; therefore the Air Bubbles near B, which are a Foot below the Surface of the Water, are compreſs'd only by the ſuperincumbent Water; which Preſſure is to the Preſſure of the Atmoſphere nearly, as one to thirty two, in which Ratio alſo is the Space taken up by the Air, when 'tis compreſs'd by the whole Atmoſphere, to the Space taken up in the Bubbles before mention'd; their Diameter, as has been

before ſaid, becoming equal: That is, the Bubble becoming ſixty four Times greater than at firſt it was, and ſo the Space taken up by the Air in this laſt Caſe, is to the Space (as the learned *Graveſande* has it) taken up by the Air when compreſs'd by the Atmoſphere, as 64 Times 32 (which is as 2048) to 1; and the Air compreſs'd by the Atmoſphere is reduct (according to that learned Author) to a Space ten Times leſs in a forcing Pump; and ſo the Denſity of this Air is as 20480 to 1. and extracting the Cube Roots of theſe Numbers, we ſhall find, that the Diſtances between the Center of Particles in theſe two Caſes are according to that elaborate Author, as 27 to 1.

But *Wallis*, in *Cap.* 14. *Prop.* 13. of his Mechanicks, allows a great deal more for the different Degrees of Dilatation and Compreſſion, than *Graveſande* does, and makes the Difference between Air compreſs'd into its narroweſt Compaſs, and Air dilated to its greateſt, to be as 550000 to 1. concerning which, I ſhall, in the Courſe of this Chapter, treat more at large; and to proceed with the learned *Graveſande*, ſhall conclude, that the Particles of Air are not of the ſame Nature with other elaſtick Bodies, for that the ſingle Particles cannot expand themſelves every Way into 27 Times the Space, and ſo be encreas'd 2000 Times, preſerving their Surfaces free from every Inequality or Angle, becauſe in every Expanſion or Compreſſion, the Parts are eaſily mov'd one againſt another; but as Air (which ſeems to agree with what *Wallis* has advanc'd on this Head) may be dilated much more than in this Experiment, it follows, that the Air conſiſts of Particles, which do not adhere or touch, but repel each other. To conclude what may be ſaid as to the Elaſticity of Air; *the Effects of it are the ſame as its Gravity*, and included Air acts by its Elaſticity, juſt as Air not included does by its Weight.

The Air which is loaded by the Weight of the whole Atmoſphere, preſſing every Way from the very Nature of Liquids; and the Force which it exerts does no Way depend upon that Elaſticity; becauſe whether you ſuppoſe Elaſticity or not, that Force which ariſes from the Weight of the Atmoſphere, and is equal to it, can no Way be chang'd, but as the Air is elaſtick, it is reduc'd to ſuch a Space by the Weight of the Atmoſphere, that the Elaſticity which reacts againſt the compreſſing Weight is equal to that Weight. But the Elaſticity encreaſes, and diminiſhes as the Diſtance of the Particles diminiſhes or encreaſes; and it is no Matter whether the Air be retain'd in a certain Space by the Weight of the Atmoſphere, or any other Way; for in either Caſe it will

expand it ſelf with the ſame Force, and preſs every Way; therefore if the Air near the Earth be included in any Veſſel, without altering its Denſity, the Preſſure of the included Air will be equal to the whole Weight of the Atmoſphere.

EXPERIMENT 4th, *Fig.* 8th. *Tab. Seq.* Take the Tube before mention'd, and immerge it in Mercury included in the Glaſs D C, ſo that the Air preſſing upon the Surface of the Mercury contain'd in the Veſſel, may have no Communication with the external Air; the Mercury in the Tube is ſuſtain'd at the ſame Height by the Elaſticity of the Air, as it was ſuſtain'd in the open Air.

AND this lets us in to the clear Underſtanding of a Doubt that I have my ſelf (as well as others) often had, how it comes to paſs, that the Water is rais'd in Pumps to the ſame Height in an enclos'd Well, as it does in the open Air in a Pond, or the like, when there is a Kerb, and other pitching and paving that ſhuts it up ſo, as that not only the Weight of the Atmoſphere, (but even the ambient Air it ſelf) ſeems to be in a great Meaſure excluded. And of this the learned *Deſaguiliers* in his experimental Philoſophy has given us ſome notable Experiments.

WHICH as well as other Experiments, which have been exhibited by Dr. *Deſaguiliers*, *Meſſieurs Watts*, *Hauksbee*, and others, are ſufficient Demonſtrations of the Elaſticity of Air. But to be a little more particular, or in other Words explain and give an Account of the Extent of this Elaſticity, which is diſcover'd by the pneumatick and other Engines,

Varenius Prop. 10. *Par.* 329. of his *Geogr.* *&c.* relates, That the moſt ſerene Air (as he there calls it) may be ſo rarified by Fire, that it will take up a ſeventy times larger Space than before; and that it may be ſo condens'd by a Pneumatick Wind Gun, that it will take up only a 60th Part of the former Space: But *Wallis Cap.* 14. *Prop.* xiii. gives a more perfect Hiſtory of the Compreſſion or Dilatation of which Air is capable, than any other Author yet extant.

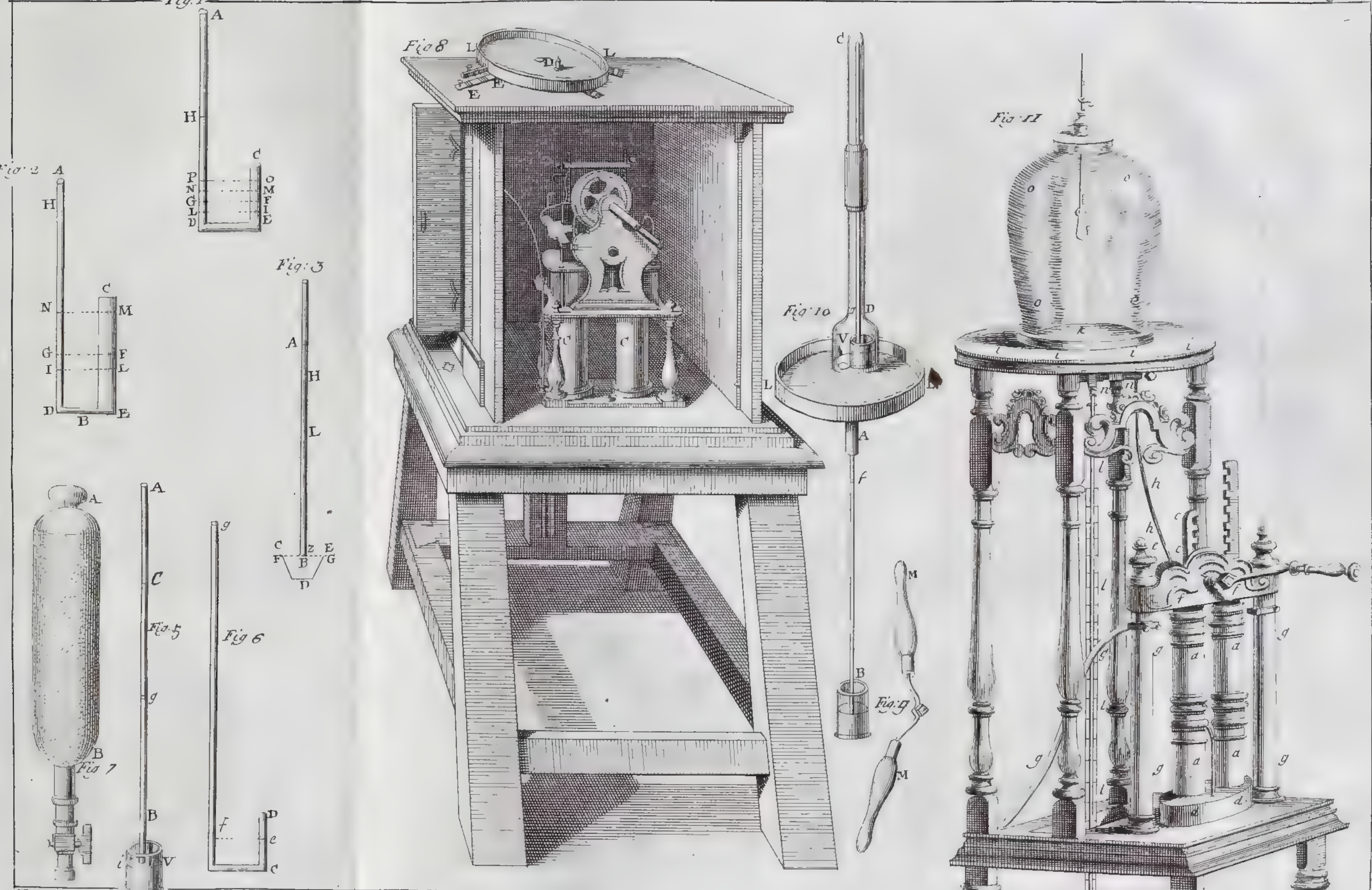
Merſennus (he tells us) long ago, by the Help of an Æliople, dilated the Air ſo, that it took up a Space 70 times as big as it was at firſt. And Mr. *Boyle*, without the Help of Heat, by elaſtick Force only, with which Air was indued, found it to dilate it ſelf firſt to 9, then to 31, then to 60, and then to more than 150, which is above double to what *Merſennus* could by the Help of Heat arrive to, as may be ſeen *inter experimenta ſua Phyſico-mechanica de aeris elatere, &c. Experim.* 6. but after that, in his Experiments *de admiranda aeris rarefactione*, he relates that in eight or nine Years time, he found that Expanſion to be much lar-

ger, even to 8000 (by its elaſtick Force only, without the Help of Heat) and having repeated the Experiment, at which our Author was alſo preſent, he found them to be larger ſtill; and therefore having appointed another Experiment, he found it come to 10000 and above (to uſe his own Words, *Pa.* 737.) *Seu pluſquam decies Millecuplum loci quam prius occupaverat idem aer, imo ad locum occupandum vicibus*, 137 69. And amongſt other very ingenious and ſubtle Experiments of the *Florentine* (*Torricelli* 'tis ſuppos'd he means) publiſh'd a few Years ſince, it is found, that Air, not only without the Help of Heat, but alſo without the Help of the Air Pump which Mr. *Boyle* uſed, might expand it ſelf into a Space 173 times larger than at firſt it was.

In like Manner, as to its Compreſſion from the Experiments of *Merſennus* juſt mention'd in a Scloppetum or Wind Gun, where, endeavouring to compreſs it, a Globule of Air, like a Flame of Fire, it burſt out with great Force, and, notwithſtanding all the Induſtry they could poſſibly uſe, they could not contract it into above a fifteenth (tho' *Varenius* before recited ſays a 60th) Part of the Room it before took up; and in the compreſſive Engine which was made for the Uſe of the Royal Society of *London*, Experiments were made, by which it was found, that Air could not be compell'd into a Space above $\frac{1}{10}$ or $\frac{1}{12}$ of its wonted Space; and Mr. *Boyle* has the ſame in his Experiments concerning the *Condenſation of Air by Cold*, in which he found, that by the help of Ice mix'd with, or made by Salt, and put into a glaſs Veſſel in which Air was included, that it could be contracted only as 147 to 158, or thereabouts, which is a great deal leſs than was generally obtain'd by Mechanick Force; for in that it loſt little leſs of its firſt Space than $\frac{11}{158}$, which is almoſt as $\frac{1}{14}$; and tho this was look'd upon to be a great Compreſſion, yet he tells us, that whilſt that Cold was ſo us'd, that it abundantly ſuffic'd to the Congelation of Water, and was much greater than the ſevereſt Winter Weather we have, being in like manner mix'd in a Veſſel (wherein was Ice or Snow mix'd with Salt) wherein alſo there was a little Air and much Water included, the Water being expanded by the Force of the Cold, ſo as to be nearly congeal'd, compreſs'd the Air in ſuch a Manner, that it was included in $\frac{1}{40}$ Part of its firſt Space; but if they had endeavour'd to contract it more, the Veſſel it ſelf muſt have been broke, which Contraction or Condenſation (ſays *Wallis p.* 738) tho it be much leſs than the Expanſion or Rarefaction juſt mention'd, yet it is a great deal more than the Cold of any great Winter, or any Mechanick Force yet produc'd could effect.

So

Plate 9 Page 228



Toms sculp

So that if we put the two great Articles of Rarefaction and Condenſation together, that is, that Air dilated is as 13679 to 1, and compreſs'd Air as 40 to 1, and multiply the one by the other, the Product will be 550760 to 1, as has been before ſet down in the Preface.

And ſo much of the Condenſation and Rarefaction; or, in other Words, of the Compreſſion or Dilatation of Air: And in Confirmation of that Elaſticity and Springineſs, which it receives from one of the great Laws of Nature, I mean, *(viz.)* its own or the mutual Congreſs of other Bodies, to which, if we add the Gravity or direct Preſſure of the Atmoſphere, we need doubt of its Effects in all Mechanick, Hydroſtatick or Hydraulick Motion; and that what the Ancients call'd *Fuga vacui*, ſome Moderns, Suction or Attraction, is really nothing leſs but Pulſion, or the external Preſſure of Air.

Thus having begun this Chapter with the Etymology and Definition of Elaſticity, I conclude it with ſuch Propoſitions and Rules, as may from the univerſal Laws, juſt mention'd, explain the Velocity of each of the elaſtick Bodies, after Percuſſion, according to the learned *Wallis*, in his Treatiſe of *Reſilition*, *cap.* 13. *pag.* 686, of his *Mechanicks*.

PROPOSITION I.

If an heavy Body in Motion ſtrikes directly upon a fixt Point, whether one or both Bodies be elaſtick: It will rebound, or be ſtruck back again, with the ſame Celerity with which it came, and by the ſame right Line.

For let A. be the heavy Body (whoſe Weight is *m* P, its Celerity *r* C, and ſo its *Momentum m r* PC) which, by the right Line A A, ſtrikes directly upon the fixt Point B. And let not either Body (whether it be the reſiſting or impelling one) be ſo perfectly hard, that it cannot any ways yield to the Stroke. Neither let it be ſo ſoft, that it may loſe its firſt Figure by the Stroke (which uſually happens in Wax, Lead, Clay, and other Bodies of ſuch Sort, either fragile or ductile) but let (one or both Bodies) have its elaſtick Force, by which it may reſtore it ſelf into its firſt Poſition, as ſoon as ever the compreſſing Force ſhall ceaſe.

And let the percuſs'd Part of the impell'd Body be underſtood as preſs'd inward by the Force of the impelling Body, it will therefore by its native elaſtick Force endeavour to reſtore it ſelf.

I ſay,

I ſay, firſt, That this Preſſure will be ſo far continued, till the elaſtick Force, which oppoſes the Compreſſion, counterpoiſes the compreſſing Force. For ſo long as the compreſſing Force is ſtronger than the Reſiſtance of the elaſtick Body, it will always perſevere to bend or compreſs the elaſtick Body.

But this compreſſing Force is double of the *Momentum* of the heavy impinging Body. For the Force brought by the heavy impinging Body, is equal to its own *Momentum* (in as much as its whole Motion is ſtopt) ſuppoſe *m r* P C. But alſo, becauſe of the equal Reſiſtance of the impelled Body, (which oppoſes the Compreſſion as much as if an equal contrary Force met it) ſo there ariſes another *m r* P C; (but which muſt have a leſs Regard paid to it, in as much as it is occaſioned ſome other way:) And therefore the whole compreſſive Force is, 2 *m r* P C.

I ſay again, That the impelling or compreſſing Force, where the Matter is reduced to a Counterpoize, ceaſes, (in as much as it is wholly ſpent in impelling the elaſtick Body.) For the Force being outwardly impreſs'd, ſuch as we ſuppoſe the impelling (otherwiſe than the natural Force, ſuch as is its Gravity, and elaſtick Force compreſs'd) where once it is brought to a Quieſcence, periſhes; nor is able to reſtore it ſelf: So that it can neither haſten it ſelf, where it is retarded. For howſoever a Body in Motion, unleſs it may be hindred, perſeveres in the very ſame: Yet it is not accelerated, or brought from Reſt into Motion, without a poſitive Cauſe.

I ſay therefore, *Thirdly*, The impelling or compreſſing Motion (as is ſaid) ceaſing, that the elaſtick Force, now free, and (as is already demonſtaated) being equal to the Force lately compreſſing, endeavouring equally on both Sides to explicate it ſelf, ſpends half its Force, or one *m r* P C; upon the impell'd Body (howſoever with a vain Attempt) and the other *m r* P C upon the impelling heavy Body. Which therefore the Body A repels with the ſame Force, and ſo likewiſe with the ſame Celerity, with which it was brought (to wit, by its Force *m r* P C and ſo, becauſe of its Weight *m* P, by its Celerity *r* C.) For an equal Force, being apply'd to the ſame Weight, moves with the ſame Celerity.

I ſay, *Laſtly*, That it will be ſtruck back again by the ſame right Line. For when an elaſtick Body is inwardly bent by a Body ſtriking directly upon it, the ſame by its elaſtick Force reſtores it ſelf to its firſt Figure, by *Def.* 1. of this Book, (and ſo returns by the ſame Way by which it was preſſed,) it imparts the ſame Direction to the Body repercuſſed, which it received from thence, unleſs that

that it may be to contrary Parts. Which therefore will return by the ſame right Line.

And, as is already demonſtrated, the elaſtick Force, being placed on the impelled Body, it obtains as much as if that Force was in the ſtriking Body, or even in both. For however that obtains, the impelling Force cannot be ſtopt before that the oppoſite Reſiſtance of the elaſtick Body (whether ſingle or double) counterpoizes; neither perſeveres farther; from whence the reſt follow.

The ſame another Way.

If there was no elaſtick Body, the Motion A would be ſtopt, being reduced to Reſt. The whole Motion therefore, which is afterwards, is from the reſtitutive Power of its elaſtick Body, and that is always equal to the Force of the Stroke. For the Force brought againſt the elaſtick Body, is equal to the Stroke (which it ſuſtains) which therefore ſo far compreſſes the elaſtick Body, till its Reſiſtance counterpoizes that. And indeed, if it was only meerly to reſiſt, the impelling Body would be at Reſt: But as an elaſtick Body reſiſts, not as a meer Impediment, but as a contrary Force, and does indeed re-act as much as it is acted upon; and the Body acted upon being equal to the Stroke or impelled Force, the reſtitutive Force alſo counterpoizes the ſame (which in the following Propoſitions has no leſs Place, and ſo muſt be taken for a Demonſtration.) But in this Caſe, ſuppoſing the Weight of the heavy Body A, to be m P, and its Celerity r C, the Greatneſs of the Stroke it produces is 2 $m\,r$ P. C. as much therefore will be the reſtitutive Force of the elaſtick Body; which therefore endeavours on both Sides to explicate it ſelf, and ſo one Half of its Force or $m\,r$ P. C. reſiſting againſt the impelled Body, however with a vain Attempt; and the other Half of its Force $m\,r$ P. C. againſt the impelling Body A. Upon account of the Weight m P. its Celerity back again will be r C. which was the Propoſition.

Again; as in all Probability there is no Body ſo firm as not to yield to the Percuſſion of another, tho' it may do it in ſo ſmall a Degree as not to be perceiv'd, and upon that Account may be diſregarded and eſteem'd as nothing; and ſo the reſiſting Body may be held immoveable (as, *e g*, when a Fly or Gnat making a Skip upon the Earth ſtrikes it) and if we conceive the thing after this Manner, we may again demonſtrate what we are upon from the 8th Propoſition of this Chapter (only changing the Order of the Propoſition)

for

for there A, a Body in Motion, is fuppos'd to impinge againft B, a Body at beft, and capable of being put into Motion: If we there fuppofe the Weight of A to be M P (which muft be fuppos'd very fmall) and its Celerity r C; and the Weight of B to be n P (which muft be fuppos'd very great) and the at the fame time at reft: Then the Celerity of the impingent Body A after Contact, will be $\frac{m - n}{m + n} r$ C forwards. (By Propofition eighth of this Chapter) that is according to the Prevalence of the Character—, for n P is fuppos'd much greater than m P,) $\frac{n - m}{m + n}$ r C backwards; which will be the fame in this Cafe, as $\frac{n}{m}$ $r\,C = r\,C$ backwards; and this proceeds from the fmall and trifling Magnitude of the Weight m P, compar'd with the vaft one of the Weight n P. Moreover, the Velocity of the remaining heavy Body B, will be after Contact $\frac{2\,m}{m + n}$ r C; which, confidering the fmall and infignificant Ratio of m, or $2\,m$, to n, or its much fmaller Proportion ftill to $m + n$, is hardly worth mentioning; fo that the Body B may not improperly be faid to be unmov'd. But if this will not be admitted, and the Obftacle B not be imagin'd perfectly immoveable; then its Fixednefs fhall be reckon'd equal to the quiefcent Weight n P, which may be efteem'd as infinite, tho' it is not abfolutely incapable of being mov'd; for there is no finite Body which may not be mov'd, unlefs hinder'd by fome foreign Caufe. (*Vid. Prop.* 8th) The Velocity therefore of the impingent Body A in its Rebound after Collifion (*vid. Prop. the* 8th) $\frac{n - m}{m + n}$ r C, will really be $\frac{\infty - m}{m + \infty}$ r C; which is the fame as $\frac{\infty}{\infty}\, r\, C = r\, C$, as appears from the infinitely fmall or no Proportion of the finite m to the finite ∞. And the Velocity $\frac{2 - m}{m + n}$ r C after Contact, of the quiefcent Body B, will be $\frac{2\,m}{m + \infty}$ r C, which is the fame (by reafon of the finite m, and the infinite n) as $\frac{2\,m}{\infty}$ r C, or $\frac{0}{\infty}$ r C, which is as no Velocity; and confequently B may be reckoned not to move, as has been demonftrated elfewhere.

SCHOLIUM.

I am not ignorant that many place a fort of unintelligible mechanical Power, in fome continued Motion fuppofed to be always exifting, by

by which Power (if the Body happens to be ſtopp'd) only by a Change of the Direction it rebounds, without any new Cauſe: But as this is only ſaid *gratis*, and is no more than a bare *Poſtulatum* (that a freſh Motion ſhould be produced without any freſh Cauſe) and at the ſame time is to be urged with great Difficulties; ſo what chiefly convinces me of its Falſity, is, that as any Obſtacle is of it ſelf ſufficient to diminiſh Motion, (ſo that a Body ſhall be hinder'd from proceeding forward by it) ſo there ſeems Occaſion for ſome poſitive Power to effect the Contrary. And as this poſitive Power is readily found in elaſtick Force, I ſee no Reaſon why we ſhould reject it; eſpecially ſince we may obſerve, that from any ſoft or fluid Body impinging againſt a ſolid one, all Motion is entirely ſtopp'd, but no Rebound made at all.

But yet, if the Body be of ſuch a Nature, that it be neither ſo ſoft as to have no elaſtick Power remaining in it, nor yet ſo very elaſtick, but it will allow ſome Change to be made in its Figure, without having all its elaſtick Fibres entirely broke; there will then be ſome Rebound made, tho' an imperfect one. (For 'tis all along ſuppoſed in the Demonſtration, that the elaſtick Power is ſufficient to bear the Shock of the impellent Body, without ſuffering a Fracture thereby.) Beſides, we find that this happens in ſome Meaſure from the Reſiſtance of the *Medium;* likewiſe, by which the Motion, whether direct or reflex, is ſenſibly diminiſhed, as likewiſe from the natural Deſcent of heavy Bodies, whereby the Motion of one Body becomes blended with that of all others: But theſe Conſiderations, and all others of the like ſort, we ſet aſide as extrinſick.

But it is to be obſerved, That however we ſuppoſe the impellent Force, as entirely owing to ſome extrinſick Impreſſion, and ſo wholly to ceaſe when the impreſſed Body is reduc'd to an equal Degree of Reſiſtance; yet it may be, that this Force may in ſome meaſure be natural, taking its Riſe from the Principle of Gravity; as imagining the impelled Body projected downwards, or elſe deſcending with a conſtantly accelerated Motion, it may acquire that Force, with which it ſtrikes againſt the Obſtacle.

The Force therefore extrinſically impreſſed, is to be ſeparated from that which proceeds from the Principle of Gravity, ſimply conſidered; and the firſt may be wholly loſt, while this remains, and ſhall ſo far leſſen the elaſtick Force, that the Rebound ſhall be made more imperfect, and with leſs Velocity; nay, it may be proved ſo conſiderable, as to overcome the elaſtick Force to ſuch a Degree, that altho' it may rebound (by reaſon of the external Impreſſi-

on being taken off, by which it was at firſt compreſs'd) yet it ſhall not be ſufficient to drive the impacted Body from it.

But ſtill, the Degree of Motion, which is acquired by Acceleration, is to be ſeparated from that owing to its natural Gravity: For any accelerated heavy Body, if ſtopt by any Obſtacle in its Progreſs, ſtill retains its natural Gravity, tho' it loſes its acquired Velocity; and thence forwards it begins to go on, as if juſt put into Motion, without any reſpect had to its former acquired Celerity, which is now loſt.———But if it ſhould be objected againſt this Hypotheſis of elaſtick Power, that all hard Bodies whatever have this Property of Repercuſſion or Reflexion, and in a Degree always proportionate to their Hardneſs or Firmneſs; yet may this be very well accounted for, without any Danger to our Hypotheſis of elaſtick Power. And this only by ſuppoſing all hard Bodies to be likewiſe elaſtick, which I ſee no Reaſon to deny. And altho' the harder they are, the leſs they give way to any Preſſure; yet they do give Way ſomething; and the leſs they give Way, the more forcibly they reſiſt and repel. And altho' we conſider Hardneſs ſeparately from Elaſticity, that we might the better demonſtrate what would follow, if there was no elaſtick Power; yet do we not thereby deſign to deny an elaſtick Power in Bodies ſimply hard; ſince in all Liklihood there are no Bodies ſo ſimply hard, as to have no Elaſticity: (Tho' there may be Bodies ſo ſoft as to have none.) And indeed, to ſpeak the Truth, I fully believe, that either there are no hard Bodies, which are not elaſtick; or, if there are ſuch, then upon their Congreſs, there follows no Rebound, but they obſerve the Laws laid down elſewhere. And that in Marble, Glaſs, Wood, Earthen Ware, and the harder Sort of Metals, there is an elaſtick Power, is plain not only from the Sound which we hear, (which is either more confus'd or diſtinct, as the Repercuſſion is ſlower or quicker) but from their remarkable Trembling, ſo plain both to the Sight and Touch.

PROPOSITION II.

If an heavy Body in Motion ſtrikes obliquely on an immovable Obſtacle, and ſuppoſing one or both of them to be elaſtick, the Rebound will be with the ſame Celerity (in the ſame Plane) and in ſuch a Manner, as to make the Angle of Reflection equal to the Angle of Incidence.

Let

Let there be ſuppoſed a heavy Body ſtriking upon the fix'd Plane A B C, ſtreight along the oblique Line O B, making the Angle of Incidence O B A. Let this oblique Motion thro' O B be conſider'd as compounded of two Motions; one Parallel, as O P or A B, the other perpendicular as P B; the former of which (being a Parallel) ſtrikes not at all againſt the Plane A B C, nor is at all impeded by it; ſo that it ſtill continues to go on with the ſame Celerity it did at firſt; *i. e*. In the ſame Time it was carried from O A to P B, it will in equal Time be carried (an equal Length) from P B to Q C. But in the other Line (which is a perpendicular) it will ſtrike directly upon the Plane A B C thro' the Line P B: And ſo, at the Point of Incidence B, it will be directly return'd thro' the Line B P, with the ſame Force, and conſequently with the ſame Celerity, by Reaſon of its elaſtick Power; That is, it will be carried in the ſame, or in equal Time from A C to O Q, as it was from O Q to A C; that is again, in the ſame, as from P C to Q C: And ſo thro' the right Line B Q. And furthermore, by Reaſon O P is equal to P Q, and P B, or B P, being common to both; (and all of 'em run thro' in equal Times) the Triangle B P O will be equal to the Triangle B P Q (and both of them too in the ſame Plane, by Reaſon of the right Line O P Q.) So then the Angle P B Q is equal to the Angle P B O: And likewiſe the Angle P B Q is equal to the Angle P B O, and (the remaining Angle at the right one) Q B C, which is the Angle of Reflexion, is equal to (the other remaining Angle at the right one) C B A, which is the Angle of Incidence.

SCHOLIUM.

If any young Beginner (or one who has made ſome Proficiency this Way) ſhould ask, Why I affirm the direct and ſimple Motion, thro' the Line O B, to be compounded of two others; or, if I muſt have it compounded, ſince this might as reaſonably be done a Thouſand other Ways; why do I, omitting all the reſt, without any Shew of Reaſon, prefer this Way to all others? (for I neither prove it to be compounded, or to be ſo no other Way but this). To theſe Queries I have this to anſwer, That there is no Motion whatſoever ſo ſimple, but is reſoluble into many component ones; and as for my chuſing this Way rather than any other, I uſe that Liberty I have of ſelecting out of ſeveral Compoſitions, that which ſerves my preſent Occaſions beſt; nor need I prove, that this Compoſiti-

on alone is poſſible ; but 'tis enough to ſay, it is one out of many: And it is free for every Author, to chuſe out among many Truths, that one which moſt conduces to his preſent Deſign.

And (that I may illuſtrate this Affair by other Compoſitions) this Method obtains in other Caſes, as well as the preſent one: For it is known, that the Number 12 is compounded of 3 + 4, and 2 + 6, and of 1 + 12 (beſides innumerable otherwiſe by broken Numbers). If therefore the Number 12 were given to be divided by the Diviſor 2, and the Quotient ſhould be ask'd: The Anſwer would be, That the Number 12 was compounded of 2 + 6; therefore the Diviſor 2 being taken, the Quotient will be *6*. But if any one ſhould pertinaciouſly ſuggeſt, that this Number 12, of which we are diſcourſing, is not at all made up of ſuch a Compoſition, but by a bare Collection of Units only (juſt, for Inſtance, as a Collection of ſo many diſtinct Men would be). Why therefore ſhould I, without any Proof, affirm a Number (form'd merely by Addition) to be a compound one, by multiplying it? And beſides, if I muſt have it compounded by multiplying; why muſt I aſſert it to be compounded of 2 x 6, when it may with equal Reaſon be ſaid to be a Compound of 3 x 4, or 1 x 12? Nor do I give any Proof why it is compounded that Way, rather than any other? Now, I ſay, would any one think ſuch an Objector as this worth liſtning to? Does not any one preſently ſee what would be the Anſwer; That the Number 12 is not at all the Leſs compounded of the Factors 2 + 6, for its being form'd by Addition? For when a Number is once form'd, by whatever Way that be, it never upon that Account loſes its proper Affections. And why I did not ſay that it was compounded of 3 + 4, or 1 + 12 (tho' all this, and much elſe, is very true) but only of 2 + 6, is very eaſily accounted for, *viz.* by ſaying, that this Compoſition tended moſt to the Matter in hand, without denying all the others to be true too; for the Number ſought for, was not one, which compounded of 1 or 3 or 4, would make 12, but that which would do it by 2.

In like Manner, ſince the Ratio between A and B may be ſhewn a 1000 Ways; as for Inſtance, either from that of A to C, and C to B; or from that of A to D, and D to B, or from A to E, and E to B, &c. yet ſuppoſing the Ratios given between A and B (E. G. let it be that of 1 to 2) and likewiſe between A and C (ſuppoſe of 1 to 3); and it ſhould be demanded, what is the Ratio of C to B: It may be anſwer'd, not that the Ratio of A to B is compounded of A to D, and D to B; or of A to E, and E to B (for thoſe Compoſitions, however juſt, yet are not to the

the preſent Purpoſe) but of A to C, and C to B: And ſo, if from the Ratio of A to B (one of the Components) be found out that of A to C, then will the remaining one likewiſe of C to B, be found too, (ſuppoſe of 3 to 2.)

$$\frac{A}{B} = \frac{A}{C} + \frac{C}{B} = \frac{A}{D} + \frac{D}{B} = \frac{A}{E} + \frac{E}{B} \text{ \&c. } \frac{A}{C}\Big) \frac{A}{B} \Big(\frac{C}{B} \cdot \frac{1}{3}\Big) \frac{1}{2} \Big(\frac{3}{2}.$$

But if any one ſhould demand, why I without any Proof affirm the moſt ſimple Ratio of 1 to 2, to be compounded: Or why juſt ſo compounded, when it might as well be done a 1000 other Ways; there is no Doubt to be made, but this is a very trifling and injudicious Queſtion: Since no Ratio is ſo intirely ſimple, as not to be reſoluble into many others: Nor need there be any other Reaſon given why I prefer this Compoſition to all others, but its being the propereſt for the preſent Subject.

In the ſame Manner, if any one ſhould demand the Velocity of a heavy Body, whoſe Momentum is ſuppoſed mr P C, and its Weight (*pondus*) $2m$ P. The Anſwer I would give, ſhould not be mr P C $= m$ P $\times$ r C, or $= r$ P $\times$ m C (which are all true, and proper enough in other Places, tho' not ſo here.) But I would ſay, mr P C $= 2m$ P $\times \frac{1}{2} r$ C; and ſo the Velocity ſought for, to be $\frac{1}{2} r$ C: For the Queſtion was not with what Celerity the Weight m P, or r P, but with what Celerity the Weight $2m$ P muſt be carried to have its Momentum mr P C.

And this is exactly applicable to our preſent Caſe. For ſince it is plain (which no one can deny) that the Motion O B is the ſame as that compounded of O P and P B; why then ſhould not I ſay, that the Motion O B is compounded of O P and P B, or, which is the ſame, is reſoluble into them? For the ſame Reaſon, as if, knowing the Number 12 to be the ſame with that Compounded of $3 + 4$, I ſhould ſay, the Numb 12 to be a Compound of $3 + 4$? And altho' it may be compounded ſeveral other Ways, yet I choſe this, as beſt ſuiting my preſent Deſign. As I might do likewiſe, if upon another Plane, I ſhould chooſe another Compoſition: For if inſtead of the Plane A B C, I ſhould take α B γ; I ſhould then ſay, that the ſame Motion O B was compounded of O π and π B, and not of O P and P B: And ſo by Reaſon O π and $\pi\chi$ being equal, in the ſame ſtrait Parallel; and B π being the ſame or equal to π B, the Reflection would be in the right Line B χ; and the Angle of Reflection χ B γ, would be equal to the Angle of Incidence O B α.

I exhibit theſe Compoſitions (reſpectively) not upon Account of their being the only true ones, but choſen as the fitteſt for the Purpoſe in Hand: And here it may be proper to obſerve, that all that Part of the oblique Motion O B, which is oppos'd by the Plane A B C, or α B γ, muſt be conſider'd ſeparate from that which is not ſo oppos'd; and this could no otherwiſe be done, but by reſolving the oblique Motion into a Parallel and perpendicular one. And this is ſo clear, that no Illuſtration need have been given, if it had not been ſeriouſly objected againſt by one, no Novice in this Way.

PROPOSITION III.

If two heavy Bodies, equal to one another, meet each other directly, with equal Celerity; and ſuppoſing one or both to be elaſtick: Or if the Bodies are unequal, and their Celerities reciprocally proportional (ſo that their Momentums may at leaſt be equal): One of them will be reflected with the ſame Celerity wherewith it ſtruck, and in the ſame right Line.

Thus, let us ſuppoſe the two heavy Bodies A, B, meeting one another according to theſe Rules: And let the Weight of both be m P, and their Celerity r C; or let the Weight of that be m P, and its Celerity r C; and the Weight of this r P, and its Celerity m C; ſo that in either Caſe, the Momentum of either of them may be $m r$ P C, and ſo of both taken together, 2 $m r$ P C. And ſince the elaſtick Power (whether ſingle or double) of both of them, muſt ſuſtain a Shock, and will continue to be bent inward, till its Reſiſtance becomes equipollent to that of both the Bodies, and then the impellent Force (being by this Means reduc'd to reſt, and ſo quite loſt) ceaſes to act. Then the elaſtick Principle, by its own Force, (ſuppoſed equal to that of the impellent Bodies) endeavours to free itſelf equally on either Side, and ſo repels the heavy Bodies on either Side with the ſame Force $m r$ P C (the Half of the whole) *i. e.* with the ſame Force with which they came together, and ſo with the ſame Celerity reſpectively: That is, ſuppoſing the Weight on both Parts to be mP, with the Celerity on either Side r C, (but only different in Directions): But if their Weights be different, the Weight m P will be repell'd with the Celerity r C, and the Weight r C with the Celerity m C; (becauſe $m r$ P C $= m$ P $\times$ r C $= r$ P $\times$ m C.) *i. e.* either of them with the ſame Celerity with which it came. And this Return will be in the ſame right

right Line (only by oppoſite Motions) becauſe the elaſtick Power endeavours to recover itſelf in the ſame Direction it was preſs'd, by its ſtriving to reſtore its former Figure ; which is to be underſtood in all the ſubſequent Propoſitions ; and ſo may there be taken for demonſtrated.

This Propoſition another Way.

If there was no elaſtick Power, both the Bodies would ſtop and be at Reſt ; and conſequently, the whole of the Motion which follows proceeds from the reſtitutive Principle of the Elaſticity, which is always proportionable to the Force of the Shock ; in this preſent Caſe, it will be $2\,m\,r$ P C ; which being divided by an equal Endeavour on both Bodies to free itſelf, acts on either Side as m r P C ; and ſo repells the Weight m P with the Celerity r C, and the Weight r P with the Celerity m C as before.

PROPOSITION IV.

If two elaſtick Bodies (not compreſs'd together) are both ſuppos'd at Reſt ; or both of them are carried with equal Velocity in the ſame right Line towards the ſame Place, or the Antecedent be carried with greater Velocity ; (whether they are contiguous or disjoin'd) there will then be no Impulſe, or Compreſſion of the elaſtick Force ; and conſequently no Change of Motions.

And therefore, if in heavy Bodies otherwiſe mov'd, a Celerity common to both be either added or ſubſtracted therefrom, thence follows no Change of Impulſe ; (or any of thoſe things which happen from ſuch a Change). But every thing is the ſame (as to the Impulſe or Compreſſion of the elaſtick Power) whether that common Velocity be there or not.

This Propoſition is very evident, for if both the Bodies are at Reſt, no Shock is given to either, no Motion obſtructed, neither impells the other, and conſequently there is no Compreſſion of the elaſtick Power, which proceeds from Impulſe, nor any Change of Motions from either (whether as to the Celerity, or Direction) let the Bodies be never ſo nigh, much leſs if they are disjoin'd. And this in like Manner would be the Caſe, if the Bodies are carried towards the ſame Place with the ſame Celerity : For if at ſetting out they are disjoin'd, they will always remain ſo, and at the

ſame

fame Diftance too from each other, by reafon of the fame Celerity in both; fo that they cannot fo much as mutually touch each other, much lefs impel. And if they are fuppofed contiguous; yet while the Body before flies with the fame Celerity, with which the hinder one follows, there cannot poffibly be any Shock given, nor any Obftruction; (and confequently there will be no Impulfe, no Compreffion, nor any Change) of Motion. But if the Velocity of the antecedent Body be greater than the others, it will be fo far from being prefs'd by the tardy one behind, that this will ftill lofe Ground; and tho' they were contiguous at firft, there will now be fome Diftance between; and if there was a Diftance at firft, this will ftill be encreas'd. Yet I add, *fo that they be not mutually compreffed together:* For if this happens, the elaftick Force will then exert it felf, as foon as poffible, and fo make fome Change of Motion.

AND for the fame Reafon, the Corollary alfo is plain: For in Proportion to the Celerity, with which the antecedent Body flies forward, and withdrawing it felf declines the Blow, will its Non-Refiftance be to the following one, and the Obftruction of its Motion, from whence arifes the Impulfe and Compreffion (not greater than when the antecedent Body withdraws it felf from the following contiguous one;) but the whole impulfive or compreffive Force muft be eftimated from the Excefs of the Celerity of the following Body above that of the antecedent one, moving towards the fame Place; which, however great it be (or whatever Motion is added or fubftracted) is common to both.

This demonftrated another Way.

THUS, by Reafon of the common Motion of both Bodies, there is no Collifion made, or at leaft, no Change of the Collifion. And therefore no Compreffion of the elaftick Power (or of what follows from thence) to be equipollent to the Shock.

PROPOSITION V.

Let an heavy Body in Motion ftrike directly againft an equal Body at Reft, (but not hinder'd from Motion,) and let one or both of them be elaftick; then the Body in Motion fhall remain at Reft, and the quiefcent Body fhall proceed with the fame Velocity which the firft moving Body had.

LET

LET the Weight of both these equal Bodies A, B *(Fig. 1. Tab. Seq.)* be m P. Let B be suppos'd at Rest, and A to strike directly against it with the Celerity r C; *i. e.* with the *Momentum* or Force $m\,r$ P C $= m$ P $\times$ r C. By this Means a Force equipollent to this would be impress'd upon the elastick Power, by the Body A (stripping it self of the same) by which (if retain'd) the elastick Power would repel the Body A (being reduc'd to Rest) supposing B to be immovable, (not to mention what is return'd from one Obstacle to another): But by Reason of the unimpeded Body's B 's giving Way, the elastick Principle gives the same Force to the yielding Body B, which it receiv'd from A (and does not retain it in itself as in the Case, *Prop.* 1. by which Means it might afterwards repel the Body A.) From whence it happens, that the impellent Body A (being depriv'd of all its Force, which it had spent on the elastick Principle) becomes quiescent; and the Body B is propell'd with the Force $m\,r$ P C (given to it by Means of the elastick Principle.) And so, by Reason of the Weight m P, is carried forwards with the Celerity r C, which was that of the impellent Body.

Another Demonstration of this.

LET there be two equally heavy Bodies, and the Weight of each be m P: Let the Body A strike directly against the quiescent Body B, with the Celerity r C, and so with the Momentum or Force $m\,r$ P C. By which Means, by the yielding of the unimpeded Body B, they would jointly be carried, if there was no elastick Power, with the half Celerity $\frac{1}{2}\,r$ C forwards; because $m\,r$ P C $=$ 2 m P $\times$ $\frac{1}{2}\,r$ C. But by Reason of the elastick Power, a restitutive Force is impress'd upon the elastick Principle equipollent to $m\,r$ P C (for as long as the bending of the elastick Power is easilyer effected than the Process of the heavy Body; that Power will be bent; and with the same Force with which it is bent, will it, by Reason of its Springyness, recover itself again. The elastick Power therefore, endeavouring to explicate itself on every Side, (the Weight of both Bodies being substracted) repels the Body A, with the Force $\frac{1}{2}\,m\,r$ P C; and with the same Force $\frac{1}{2}\,m\,r$ P C propels the Body B. that is, (by Reason of the Weight, on either Side, m P,) the Body A backwards with the Celerity $-\frac{1}{2}\,r$ C, and B forwards with the Celerity $+\,r$ C. But A was to be carried, under another Denomination, (as has been observ'd) with the Celerity $+\,r$ C, forwards; therefore, as by this Means there is added the Celerity $-\,r\,c$, backwards, A will remain at Rest (or which is the same, will

not be mov'd with any Celerity towards either Part) by Reaſon $+\frac{1}{2} r C - \frac{1}{2} r C = o C$. The Body B alſo was to be mov'd under another Denomination, (as has been ſhewn) with the Celerity $\frac{1}{2} r C$, forwards; but by this Means it is alſo propell'd with the Celerity $\frac{1}{2} r C$, forwards; therefore the whole Celerity is $\frac{1}{2} r C + \frac{1}{2} r C = r C$, forwards; *i.e.* the ſame which belong'd to the firſt mov'd Body A.

Or thus in a ſhorter Way.

Every Thing ſuppoſed as before; both the Bodies would be carried forwards with the Celerity $\frac{1}{2} r C$, if there was no Elaſticity; and ſo both with the Momentum or Force $\frac{1}{2} m r P C$; the Greatneſs of the Shock is $m r P C$; and then the reſtitutive Force of the Elaſticity, being equal to this, by endeavouring to free itſelf on all Sides, repels the Body A with half its Force, and with the other Half propel's the Body B; ſo that it communicates to A the Force $-\frac{1}{2} m r P C$, backwards; and to B, the Force $+\frac{1}{2} m r P C$, forwards; which reſpectively added to what had been laid down before; the Force upon A will be $\frac{1}{2} m r P C - \frac{1}{2} m r P C = o P C$, which therefore will remain at Reſt; and the Force upon B will be $\frac{1}{2} m r P C + \frac{1}{2} m r P C = m r P C$, forwards; which therefore, (upon Account of the Weight $m P$) will be carried forwards with the Celerity $r C$, which was that of A.

Another Demonſtration.

Let the two heavy Bodies A, B, be ſuppos'd equal, as before; and let A ſtrike directly againſt B at reſt, with the Celerity $r C$ forwards. Let there be ſuppos'd alſo to be ſuperadded to both, a common Motion, with the Celerity $-\frac{1}{2} r C$, backwards; by which Means the Celerity of A will be $r C - \frac{1}{2} r C = \frac{1}{2} r C$, forwards; and the Celerity of B will be $-\frac{1}{2} r C$, backwards: In which Caſe, the Body A, after Congreſs, will be carried with the Celerity $-\frac{1}{2} r C$, backwards; and B with the Celerity $+\frac{1}{2} r C$, forwards: But, (by Reaſon of the common Motion, which is as nothing, as far as it reſpects the Impulſe) there will be the ſame Effect of the Impulſe in the preſent Caſe: If therefore they be reſtor'd to their former State, by taking away on both Sides the Celerity which was added $-\frac{1}{2} r C$ (or which comes to the ſame Thing, by adding the Celerity $+ r C$, forwards) then will the Celerity of the Body B be found $-\frac{1}{2} r C + \frac{1}{2} r C = o C$; and the

the Celerity of B to be $+\frac{1}{2}rC+\frac{1}{2}rC=rC$. That is, A will remain at Reſt, and B will be carried forwards with the Celerity that before belonged to A.

SCHOLIUM.

I have here collected ſeveral Demonſtrations (as I have done the ſame in other Propoſitions) not that I diſtruſt the Force of any ſingle one (or would be ſuppos'd willing to ſupply Want of Reaſon by Redundancy of Numbers) for every one, I think, carries its own Evidence; but I did it to ſuit the different Taſtes of different Readers, who ſometimes prefer one Method of Demonſtration to another: The firſt indeed, and ſecond do more clearly explain the phyſical Cauſe of the Thing, which yet I proſecute more ſparingly in the following ones, as what depends upon theſe. And the laſt but one (taken from a Conſideration of the Force, if there had been no Elaſticity, and of the reſtitutive Force of the Elaſticity, always equal to the Impreſſion) are the beſt accommodated to my Hypotheſes, and are, if I miſtake not, true Geometrical Demonſtrations. I have likewiſe added the laſt for the Sake of thoſe who do not ſo readily aſſent to thoſe Hypotheſes of mine (which as yet are not generally receiv'd) for by this Method (which as well as the other I likewiſe accommodate to the following Propoſitions) which, ſetting aſide all others, draws the following Propoſition by a juſt Calculus, only from admitting *Prop* 3. and 4. of this Chapter, (which others, rather than endeavour to prove them, eſteem as Poſtulatums, as evident in themſelves, and prov'd by phyſical Experiments). By this Method, I ſay, it happens, that whatever Doubt there be of thoſe Hypotheſes, which yet I take as mighty juſt and true, yet is there no Room left to doubt of the Truth of the Propoſitions; which depends no otherwiſe upon my Hypotheſes, than that I from thence prove the third Propoſition of this Chapter, which others eſteem, without any Proof, a Poſtulatum. And I likewiſe thought it not at all an improper Undertaking, to ſhew the Conſent of each Method: So that the Phænomena of Motion in our Hypotheſes (altho' deduc'd from other Principles, and the Hypotheſis itſelf, afterwards publiſh'd in the philoſophical Tranſactions, was firſt exhibited to the Royal Society, and inſerted in their Regiſters, before either of the others were made publick or exhibited) are plainly the ſame with the Phænomena of the Hypotheſis of our own Countryman the late Sir *Chriſtopher Wrenn*, and the Dutchman *Chriſtian Hugens*. But ſtill there is this Difference between them;

 that

that what they demanded as Poſtulatums, or infer from Obſervations, wherein no Regard was had to the Principle of Elaſticity; we, by Means of this Principle, deduce from firſt Principles, while at the ſame Time, the Phænomena which we collect from thence by Reaſoning, proceed upon the ſame Foundation theirs do, *viz.* from approv'd Experiments which they had obſerv'd. So that upon that Account there would be leſs Occaſion to doubt of the Truth of our Conſent in theſe Appearances, ſince each of us, without the Knowledge of the other, upon different Principles, and by different Methods, arriv'd at the ſame Phænomena.

PROPOSITION VI.

If two elaſtick Bodies, equal to each other, are carried in the ſame right Line towards the ſame Part, by unequal Celerities; and the hindermoſt one, being carried with the greater Celerity, ſtrikes directly againſt the antecedent one; after Impulſe, they ſhall be both carried in the ſame Direction, but with interchang'd Velocities.

LET the Weight of both theſe equal Bodies A and B be m P; let the Velocity of A be $r\,C = s\,C + t\,C$; and of B, s C: So that the Momentum of A will be $m\,r$ P C, and of B, $m\,s$ P C, both forwards; upon which Account the reſtitutive Force of the elaſtick Principle (being always equal to the Shock) will be $m\,r\,P\,C - m\,s\,P\,C = m\,t\,P\,C$; which by attempting equally on all Sides to diſengage itſelf, will, with the one Half of its Force $\frac{1}{2}\,m\,t$ P C, repel A, and with the other urge forwards B. So by Reaſon of the common Weight m P, it communicates to A the Celerity $-\frac{1}{2}\,t\,C = -\frac{r-s}{2}\,C$, backwards, and to B the Celerity $t\,\frac{1}{2}\,t\,C = +\frac{r-s}{2}\,C$ forwards. But if otherwiſe, there was no Elaſticity, then both would be carried with the Velocity $\frac{r+s}{2}\,C$; which being added on both Sides, the Celerity of A will then be $-\frac{r-s}{2}\,C + \frac{r+s}{2}\,C = s\,C$; and of B $+\frac{r-s}{2}\,C + \frac{r+s}{2}\,C = r\,C$; that is, both will proceed forwards, with interchang'd Velocities.

Another Demonſtration of this.

LET the two equal Bodies be A, B *(Fig. 3. Tab. Seq.)* and let the Celerity of the antecedent one B, be s C, and of the hinder Body A, let the Celerity (which muſt here be ſuppos'd the greater of the two) be

be r C $= s$ C $+ t$ C. Since then the Celerity s C is common to both, 'tis the same in Effect (as to the Compression of either) as if it was supposed to be taken away on both Sides. Therefore the hinder Body A, will strike upon the quiescent one B, with the Excess of its Celerity t C. In which Case B, after Collision, will be driven forwards with the Celerity t C, which was that of the following one A; and A, as if now at Rest, with the Celerity o C: If then the common Celerity s C (just now suppos'd taken away) be again restor'd to both, then will the Celerity of A be found to be o C $+ s$ C $= s$ C; and the Celerity of B t C $+ s$ C $= r$ C: that is, both will be continued in the same Direction, with interchang'd Velocities.

PROPOSITION VII.

If two elastick Bodies equal to each other, (being carried to opposite Parts in the same right Line) directly meet each other with unequal Celerities; after Collision they shall be return'd to contrary Parts, with interchang'd Celerities.

LET the Weight of both the Bodies, A, B, (*Fig.* 4. *Tab. Seq.*) be m P, and the Celerity of A be r C, forwards, and of B $-s$ C, backwards; and let $r + s = z$. The Momentum of A shall be $+ m r$ P C; and of B, $- m s$ P C: Therefore the restitutive Force (equal to the Blow) of the elastick Principle (which sustains both) will be $m r$ P C $+ m s$ P C $= m z$ P C; which endeavouring to disengage itself on both Sides, with the Half of its Force $\frac{1}{2} m z$ P C repels both the Bodies; and therefore, by Reason of the common Weight m P, gives to A the Celerity $- \frac{1}{2} z$ C $= - \frac{r+s}{2}$ C, backwards; and to B the Celerity $+ \frac{1}{2} z$ C $= + \frac{r+s}{2}$ C, forwards. But if there was no Elasticity, then they would both be carried with the Celerity $\frac{r-s}{2}$ C; which added on both Parts, will make the Celerity of A to be $- \frac{r+s}{2}$ C $+ \frac{r+s}{2}$ C $= - s$ C, backwards; and of B to be $+ \frac{r+s}{2}$ C $+ \frac{r-s}{2}$ C $= + r$ C, forwards; that is, to opposite Parts, with interchang'd Celerities.

Another Demonſtration.

LET the Celerity of A be r C $=$ s C $+$ t C, forwards; and of B, ſuppoſed equal to A, let the Celerity be $-$ s C, backwards; and theſe two Bodies to meet each other directly. As then the Celerity common to both is s C, but to different Parts: Accordingly after Colliſion, (by Reaſon of theſe Celerities) A will be carried with the Celerity $-$ s C, backwards; and B, with that of $+$ s C, forwards: But let theſe Celerities be ſuppoſed taken away, then there will be left to the Body A the Celerity t C, with which it ſtruck the quieſcent Body B; and, upon Account of this Celerity, the Body B will be carried forwards with the Celerity t C, and A (now quieſcent) with the Celerity o C; which, if reſpectively added to thoſe before mention'd, then will the Celerity of A be $-$ s C $+$ o C $=$ $-$ s C, backwards; and of B, $+$ s C $+$ t C $=$ $+$ r C, forwards; that is, to contrary Sides, with interchanged Celerities.

Another Demonſtration of this.

LET there be ſuppoſed two Bodies A B, which meet one another directly; A with the Celerity r C $=$ s C $+$ t C, forwards; and B with the Celerity $-$ s C, backwards. Let there alſo be given to both, (by a common Motion) the Celerity $+$ s C, forwards; by which Means the Celerity of A will become r C $+$ s C, forwards; and of B $-$ s C $+$ s C $=$ o C: (that A may be carried with the Celerity r C $+$ s C towards B as quieſcent) which being ſuppos'd; the Celerity then of A, after Colliſion, will be o C; and of B r C $+$ s C, forwards: And the ſame likewiſe will happen, in the Caſe propounded (as far as regards the Impulſe). If therefore the Celerity $+$ s C (which was added) ſhould be taken away on both Sides, then will the Celerity of A be found to be o C $-$ s C $=$ $-$ s C, backwards; and of B to be r C $+$ s C $-$ s C $=$ r C, forwards; that is, they will be carried to oppoſite Parts, with interchang'd Velocities.

PROPOSITION VIII.

If a heavy Body in the Motion, either ſtrikes directly againſt a Quieſcent one (either equal or unequal to it) with any given Velocity; (and let one or both of them be ſuppos'd elaſtick) the Celerity

rity then of the impingent Body, after Collision, shall be to the Celerity it had before, as the Difference of Weights to their Sums; and this will be either backwards or forwards, according as the Weight of the impingent Body is less or greater than that of the Quiescent one; and if both are equal, then will it remain at these. The Celerity likewise of the Body at Rest, (after Collision) will be to that of the impingent one, as double the Weight of the Impingent, to the same Sums of their Weights; and therefore, supposing their Weights equal, its Celerity will be that of the first mov'd Body.

LET the Weight of the Body A in Motion be m P, and its Celerity r C, and its Momentum consequently $m\ r$ P C: And let the Weight of the Body at Rest (which A strikes directly against) be n P; Then will the restitutive Force (always equal to the Shock) of the Elasticity be $\frac{2\,m\,n}{m+n}\,r$ P C, which, by attempting to free itself equally on all Sides, will, with the one Half $\frac{m\,n}{m+n}\,r$ P C of its Celerity, repel A, and with the other drive forwards B; and consequently gives to that (on Account of the Weight m P) the Celerity $-\frac{n}{m+n}\,r$ C, backwards; and to this (by Reason of the Weight n P) the Celerity $+\frac{m}{m+n}\,r$ C, forwards: But, on the other Hand (supposing the Elasticity away) they would then be both carried with the common Celerity $\frac{m}{m+n}\,r$ C, forwards, which, if added on both Sides, then will the Celerity of A be found to be $-\frac{n}{m+n}\,r\,C+\frac{m}{m+n}\,r\,C=\frac{m-n}{m+n}\,r\,C$, either forwards or backwards, according as m or n is largest; or else none at all, if these are equal, because $m-n=0$: and the Celerity of B will be $+\frac{m}{m+n}\,r\,C+\frac{m}{m+n}\,r\,C=\frac{2\,m}{m+n}\,r\,C$; and if $m=n$, with the Celerity r C. Which was to be demonstrated.

Another Demonstration.

LET the Weight of A be m P, and the Weight of B be n P; and let A be supposed to strike directly against B, with the Celerity r C; let this Celerity also r C be supposed to be divided in Parts, reci-

reciprocally proportional to the Weights, *viz.* into $\frac{n}{m+n}\ r\ C$, which may anſwer to the Weight m P, and into $\frac{m}{m+n}\ r\ C$, which may anſwer to the Weight n P. And further, let the Celerity $\frac{m}{m+n}\ r\ C$ (which belongs to B) be taken away on both Sides, or, which is much the ſame, added to the Motion backwards; (which common Addition or Subduction of Impulſe makes no Difference in our Account) then will the Celerity of A be $r\ C - \frac{m}{m+n}\ r\ C = \frac{n}{m+n}\ r\ C$; and of B, $o\ C - \frac{m}{m+n}\ r\ C = - \frac{m}{m+n}\ r\ C$, which are in a reciprocal Proportion to the Weights: Therefore they will both be return'd back with the ſame Celerities they approach'd; that is, A with the Celerity $- \frac{n}{m+n}\ r\ C$, backwards, and B with the Celerity $+ \frac{m}{m+n}\ r\ C$, forwards, and the ſame will be the Ratio of the Impulſe in the Preſent Caſe: And therefore, if the Celerity $\frac{m}{m+n}\ r\ C$ forwards, be reſtor'd on both Sides, (which was juſt now taken away) then will the future Celerity of A be found to be $- \frac{n}{m+n}\ r\ C + \frac{m}{m+n}\ r\ C = \frac{m\ m}{m+n}\ r\ C$; which will be either forwards or backwards, as m or n ſhall be greateſt (or elſe neither Way, if they are equal). And the Celerity of B will be $\frac{m}{m+n}\ r\ C + \frac{m}{m+n}\ r\ C = \frac{2\ m}{m+n}\ r\ C$, forwards, as before.

PROPOSITION IX.

If two elaſtick Bodies, either equal or unequal, be carried in the ſame right Line towards the ſame Place, with any given Velocities (tho' ſuppos'd ſuch, as that the following Body, carried with the greater Velocity of the two, ſhall ſtrike directly againſt the antecedent one). Then after Colliſion, they ſhall be both carried with the ſame Velocities, towards the ſame Parts; as will appear from the preſent Calculus.

LET

LET the Weight of the antecedent Body B be n P, and its Celerity s C forwards; let the Weight of the following one A be m P, and its Celerity (greater than the other's) r C $=$ s C $+$ t C: The reſtitutive Force (being always equal to the Shock) of the Elaſticity will then be $\frac{2mn}{m+n}$ t P C; which endeavouring equally on both Sides to explicate itſelf, will exert on both Sides its half Force $\frac{mn}{m+n}$ t P C; and ſo give to A, by reaſon of the Weight m P, the Celerity $-\frac{n}{m+n}$ t C, backwards; and to B, by reaſon of its Weight n P, the Celerity $+\frac{m}{m+n}$ t C, forwards: But then (ſuppoſing no Elaſticity) they would be carried with the common Celerity $\frac{mr+ns}{m+n}$ C; which if added on either Side, will give the future Celerity of A $-\frac{n}{m+n}t$C $+\frac{mr+ns}{m+n}$ C $=\frac{mr+ns-nt}{m+n}$ C $=\frac{mr-nr+2ns}{m+n}$ C; which will be either forwards or backwards, according as the Sign $+$ or $-$ prevails, and conſequently neither Way, if they are equal; and the Celerity of B will be $\frac{m}{m+n}$ t C $+\frac{mr+ns}{m+n}$ C $=\frac{mt+mr+ns}{m+n}$ C $=\frac{2mr-ms+ns}{m+n}$ C, forwards. *Q. E. D.*

Another Demonſtration of this.

LET the Weight of A be m P; and of B, n P, and let both be carried in the ſame right Line towards the ſame Place; ſuppoſe both forwards, and B with the Celerity s C; and A with the greater Celerity r C $=$ s C $+$ t C; and to ſtrike directly againſt B. Suppoſe alſo, by a common Motion, the Celerity s C to be taken from both; (which, as it is common to both, will make no Alteration in the Impulſe.) By which Means B will be reduc'd to reſt, (by reaſon s C $-$ s C $=$ o C;) and A will ſtrike directly againſt it with the Celerity r C $-$ s C $=$ t C. In which Caſe, A, after Colliſion, will be carried with the Celerity $\frac{m-n}{m+n}t$ C; (either forwards or backwards, as m or n ſhall prevail) and B with

 the

the Celerity $\frac{2m}{m+n}$ t C, forwards. As therefore the Reaſon (Ratio) is the ſame in the preſent Caſe (as far as regards the Impulſe) if the Celerity s C forwards be again reſtor'd on both Sides, (which was before ſuppos'd taken away) then the future Celerity of A will be $\frac{m-n}{m+n} t\,C + s\,C = \frac{mt+ms-nt+ns}{m+n}$ $C = \frac{mr-nr+2ns}{m+n}$ C; (which will be either backwards or forwards, according as the Sign + or − prevails; and conſequently neither Way, if they are equal). And the Celerity of B will be $\frac{2m}{m+n} t\,C + s\,C = \frac{2mt+ms+ns}{m+n}\,C = \frac{2mr-ms+ns}{m+n}$ C forwards, as before.

PROPOSITION X. and laſt.

If two elaſtick Bodies, either equal or unequal, directly meet each other in the ſame right Line, with any given Celerities, they will both, after Colliſion, be carried with the ſame Celerities, and to the ſame Place; as will appear from the Calculation.

LET the Weight of A be m P, its Celerity $+ r$ C, forwards; let the Weight of B, directly meeting A, be n P, and its Celerity $- s$ C, backwards: And let $r + s = z$, the reſtitutive Force (being always equal to the Blow) will then be $\frac{2mn}{m+n}$ z P C; which endeavouring to diſengage it ſelf, will equally divide its half Force $\frac{mn}{m+n}$ z P C; and conſequently will give to A, by reaſon of its Weight m P, the Celerity $- \frac{n}{m+n}$ z C, backwards. And to B, by reaſon of its Weight n P, the Celerity $+ \frac{m}{m+n}$ z C, forwards. But on the other Hand, if there was no Elaſticity, they would then both be carried with the Celerity $\frac{mr-ns}{m+n}$ C; which therefore added on both Sides, will make the future Celerity of A to be $- \frac{n}{m+n}$ z C + $\frac{mr-ns}{m+n}\,C = \frac{mr-nz-ns}{m+n}\,C = \frac{mr-nr-2ns}{m+n}$ C; which will be either

either forwards or backwards, according as the Sign + or — prevails; and conſequently neither Way, if they prove equal. And the Celerity of B will be $\frac{m}{m+n} z C + \frac{mr - ns}{m+n} C = \frac{mr + mz - ns}{m+n} C = \frac{2mr + ms - ns}{m+n} C$, which will likewiſe be either forward or backward, as the Sign + or — prevails; and neither Way, if both prove equal. *Q. E. D.*

Another Demonſtration.

LET the Weight of A be m P; and of B, n P; which are to meet one another directly: A with the Celerity r C forwards; and B with the Celerity $-s$ C, backwards; and let $r + s = z$. Let there be ſuppos'd likewiſe (by ſome common Motion, (which therefore will make no Difference as to Impulſe) to be added to both the Celerity $+ s$ C, forwards; by which Means B will be reduced to reſt, (becauſe $- s C + s C = o C$;) and A will ſtrike upon it as at reſt with the Celerity $r C + s C = z C$. In which Caſe, A, after Colliſion, will be carried with the Celerity $\frac{m-n}{m+n} z C$; and B, with the Celerity $\frac{2m}{m+n} z C$. So that now taking away the Celerity s C from both Parts, which was juſt added, the future Celerity of A will be found to be $\frac{m-n}{m+n} z C - s C = \frac{mz - ms - nz - ns}{m+n} C = \frac{mr - nr - 2ns}{m+n} C$; which will be either forwards or backwards, as the Sign + or — prevails; and neither of them, if they be equal. And the Celerity of B will be $\frac{2m}{m+n} z C - s C = \frac{2mz - ms - ns}{m+n} C = \frac{2mn + ms - ns}{m+n} C$; which will likewiſe be either backwards or forwards, according to the Prevalence of the Sign + or —; or neither Way, if they prove equal. *Q. E. D.*

BOOK. II.

CHAP. XIII.

Of the Impulſive Force of Air and other Fluids, in Hydroſtaticks.

HITHERTO we have diſcours'd of the Equilibrium of Fluids by their Gravity or Weight, and by their Elaſticity or Spring, but there is alſo an Equilibrium of Fluids which is, as it were, a Compound of both the other two; namely, by their Impulſe.

FLAME, as the very curious and ingenious *Marriotte* obſerves, can make an Equilibrium with other Weights, by its Impulſe. But as it is very rarely made uſe of to work Engines, any other than to rarify the Air in Pipes of Force, it is not neceſſary to examine in this Place, nor compare it, with other Fluids.

Now as the Demonſtration of this Impulſe, and the Equilibrium it makes with other Bodies, depends upon the Deſcent of thoſe Bodies, which are either accelerated or retarded according to the Height or Depth of the Place from whence they proceed; and whether they aſcend or deſcend: So conſequently an accelerated Motion is that whoſe *Celerity or Velocity becomes greater every Moment*, and which is the Conſequence of a Body that falls in open Air, occaſion'd by the Impulſe of the ſuperincumbent Fluid, as Air, Water, and the like; and a retarded Motion is that *whoſe Velocity is diminiſhed every Moment*, by riſing upwards in the ſame Ratio as the other is accelerated by falling downwards; and this is called the free Deſcent of a heavy Body; by which we here underſtand the Fall of that Body in open Air, when it meets with no other Body, to oppoſe its Motion; in which it is generally obſerved, that a Body (as before hinted) which falls freely in the Air, acquires in equal Moments of Time,

Time, equal Degrees of Velocity, and that the Spaces through which the Body goes, encreaſe each Moment or Inſtant of Time according to the Series of the firſt uneven Numbers, 1, 3, 5, 7, 9, *&c.* which are the Differences of the Squares 1, 4, 9, 16, 25, *&c.* of the arithmetically proportional Numbers 1, 2, 3, 4, 5, *&c.* and that conſequently the Spaces which Bodies go through from the Beginning of their Fall, are in a duplicate Ratio, or as the Squares of the Times or Moments ; and it is only by Experience, that we can account for this Proportion, which will be as a Foundation for the greateſt part of what we ſhall hereafter ſay.

PROPOSITION I.

The Space which a heavy Body goes through in a determinate Time being known, to find out what Space it will go through in a given Time.

Suppose a Body to have deſcended twenty four Foot in one Minute of Time, to find how far the ſame Body will fall in the ſame Medium in three Minutes, for Example to the Numbers 1 : 9 : : 24. the two firſt of which, (*viz.*) 1, 9, are the Squares of the given Times, one Minute and three Minutes ; and the third, *viz.* 24. is the Space gone through in the firſt Time : But to this you are to find a fourth Proportional. Which is done thus :

If 1 : requires 9, what will 24 require ?
Multiply 9

gives 216

To invert the laſt Propoſition, let us propoſe the next.

PROPOSITION II.

The Time being known in which a heavy Body deſcends through a determinate Space, to find in how long Time it will deſcend through a given Space.

Suppose a Body has ſpent one Minute in falling 24 Feet, to find what Time it will ſpend in falling, for inſtance, 216 Feet, in the ſame Medium.

Say,

Say, as 24 is to 216, ſo is 1 to the Square of the fourth Proportional requir'd.

$$\begin{array}{r} 24 : 216 . 1 \\ 1 \\ 24)\, 216 \,(9 \\ 216 \\ \hline 0 \\ \hline \end{array}$$

So that it appears the Number ſought for, is 9, the Square whereof is 3.

This being premis'd concerning the Calculation of deſcending Bodies, as Fluids, and the like, by their Impulſe, or the ſuperincumbent Weight of its own or other Bodies gravitating upon them; and it being manifeſt that an inferior Fluid is preſs'd by a ſuperior, and that equally every Way, becauſe Action is equal to Re-action, and endeavours to recede every Way equally; and becauſe Air and Water are the chief of the Fluids that are applied to the moving of Engines or Machines, for elevating of Water, and driving of Mills; it will be requiſite in the next Place to ſhew how they make an Equilibrium with each other, and how they ſtrike againſt and impel other Bodies, as we have it ſo well deſcrib'd by *Marriotte*, Diſcourſe 3. p. 116. of his *Hydroſtaticks*.

Jet's d' Eau (ſays he) *Spouts or Streams of Water do not impel with the united Force of all their Parts, as ſolid Bodies do.* Let A B, *Fig.* 5. *Tab. Seq.* be a Spout of Water iſſuing from the Cylinder C D, and I C F is a Cylinder of Wood, whoſe Parts being joined together, 'tis evident, that when the Extremity F of this Cylinder ſtrikes againſt a Body, it impels it with the united Force of all its Parts: But a Spout or Stream A B, being carried according to the Direction A *d* B, can only act by thoſe Parts that go firſt; for Water being a Fluid, and compos'd, as it were, of an infinite Number of Corpuſcles, or little Bodies, that ſlide one upon another, as ſmall Grains of Sand would do; only the firſt towards B can make the firſt Effort upon Bodies that they meet, and they either reflect or fall off before the other Parts at *d* can impel in their turn.

For the better underſtanding of this, you muſt conſider that the Velocity of Water going out at a ſmall Hole made at the Bottom of a very large Tube, is very different from the Velocity of that which iſſues from a Tube whoſe Diameter is equal throughout; for if in this latter Caſe it begins to go out very ſlowly, juſt as a Cylinder of Ice would do, that you ſhould let fall.

Exper. 2. *Fig.* 6. *Tab. ſeq.* Let A B be a Tube of equal Breadth, fill'd with Water, and ſuſtain'd with the Finger at B; 'tis evident that the Velocity of the Water when it goes out at B, is equal to that at A, and the whole Cylinder of Water falls at once, as if it were ſolid; and conſequently to the ſame Rules in falling, that a Cylinder of Ice of the ſame Bulk would be; namely, that beginning by a very ſmall Degree of Velocity, it encreaſes in its Deſcent, according to the uneven Numbers 1, 3, 5, 7, *&c.* that is to ſay, if in one Quarter of a Second it falls a Foot, the ſecond Quarter it will fall three Foot, in a third, five, and ſo on; from whence it follows, that the Water which was at A, being got to B, will go out much faſter than that which goes out firſt.

Galileo (ſays our Author) has ſpoken very largely of this Acceleration of the Velocity of Bodies that fall freely in the open Air, which may be thus conceiv'd; ſuppoſe a very light Body to ſtrike againſt another an Hundred times heavier than it ſelf, it will give the hundredth part of its Velocity, and ſtriking it a ſecond time, it will give another hundredth Part; ſo that if the impelling Body has an Hundred and one Degrees of Velocity, the impell'd Body will take one Degree at the firſt Impulſe, and its Quantity of Motion will be an Hundred; and being impell'd a ſecond time by the light Body, with the ſame Velocity of an Hundred and one Degrees, it will receive from it a new Degree of Velocity; which join'd to the firſt, will make two Degrees: The third Impulſe will ſtill add a Degree, and ſo on, the ſame thing will happen, if a weak Power draws a very heavy one to it, by acting upon it ſucceſſively. Now whether a Body be attracted or impell'd by a very light Fluid; if at the firſt Moment of its Effort, it moves in a Line by an uniform Velocity, at the ſecond Impulſe and ſecond Moment, it ought to move two, and at the third Moment three, *&c.*

Now if you take ſeveral Numbers one after another, beginning with an Unit, 1, 2, 3, 4, *&c.* to 20, and count 20 Moments, the Sum of this Progreſſion will be 210; and if you count 40 Moments, according to the ſame Progreſſion to 40, the Sum of theſe latter Numbers will be 820, which is near the Quadruple of 210, the Sum of the 20 firſt Numbers; but if you proceed thus, *in infinitum*, this laſt Sum will be the Quadruple of the firſt preciſely, becauſe the Proportion of the Defect continually decreaſes; which *Galileo* has alſo prov'd in his Treatiſe of the Acceleration of the Motion of falling Bodies.

But if the Motion be made through a very heavy Fluid, this Acceleration will ſoon be ſtopt, and the falling Body reduc'd to an uniform

form Velocity, as likewife a very light Body that falls in open Air, as has been prov'd in fome Treatifes on Percuffion.

Experiment 3. *Fig.* 7. *Tab. feq.* Take a bended Tube two or three Foot long, of equal Breadth throughout, as C D D, pour Water in at C till it runs out at G, then ftop the End G with your Finger, and pour on till you fill the Tube up to C; and after this ftop the End C with another Finger, and open the End G: If the Tube be only three or four Lines in Diameter, the Water will not run out at all; take off the Finger that ftopt the End C, and put it on again very fuddenly, the Water will fpout out at G only four or five Lines high; whereas if the Tube C D be much wider than the Hole G; for example, if it be nine Lines in Diameter, and the End only two or three Lines, and you open and fhut the fmall Aperture at G with the fame Hafte, the Drops of the Water that go out at G, will fpout up almoft as high as C.

You may ftill further perceive the Slownefs of the Water's Motion at its firft going out of the Tube, as A B in *Fig.* 2. and its Acceleration, if you fill this Tube with Water, and fuftain it with your Finger, fuftaining likewife a little Stone with another Finger on the fame Hand; for taking away your Hand fuddenly, you will fee the Stone and the loweft part of the Water defcend with the fame Velocity for twelve or fifteen Foot together. Another very curious Experiment is made in the following Manner:

Experiment 4. *Fig.* 8. *Tab. Seq.* Take a Tube eight or ten Foot long, as M N, as fmooth and even as it can be made, fill it with Water, which you muft fuftain with your Finger, and then of a fudden let it run out upon the End of the Rule Q R, near the Point R, which Rule ferving for a Ballance, ought to be horizontal, and fupported at the other End by a Prop, as O V; and the Point R ought to be only five or fix Lines diftance from the Bafe of the Tube through which the Water paffes, that is to fay, a Line more than the Thicknefs of the Finger that fuftains the Water; then if at the other End Q, you fix a Weight Q $\frac{1}{4}$ or $\frac{1}{5}$ lefs than the whole Weight of the Water in the Cylinder, this Weight will not rife at the Beginning of the Water's Fall, though the whole Body of Water feems to weigh upon R, but only when the Tube is almoft empty; which fhews, that only the firft Parts of the Water make an Impreffion, and that when they go out very flowly, as they do at the Beginning of their Fall, they can only raife a Weight much lefs than the Weight of the whole Cylinder; but when they have acquired a great Velocity in falling from the Height M, the remaining Parts, by their great Impulfe, raife what the firft could not raife by their weak Impulfes

pulſes at the Beginning of a Fall; juſt as the Wheel of any Machine, which by the Impulſe of the firſt Water that falls upon it ſeems to move a little, yet is not ſet into its uniform and regular Motion without the Acceſſion and Impulſe of the other Water that is to drive it.

To go on; If you raiſe the ſame Tube two or three Feet above R, and leave only one Inch of Water at the Bottom of it, (if the Tube be ſeven or eight Lines Diameter) it will have leſs Force in falling upon R to raiſe a Weight at Q, than a little Ball of Wax or Wood lighter by half than the Water falling from the ſame Height; which ſhews that the Ball makes its Impreſſion by all its Parts, and the Inch of Water only by thoſe that are neareſt to the firſt Surface that impels the Ballance, and which are help'd a little by the more diſtant Parts that fall on each Side.

For though Water does not impel by all its Parts, and it be difficult to determine the preciſe Height of the Water from which the Part impelling ought to be eſtimated; yet 'tis probable that the Parts that fall firſt act the moſt, and that thoſe that are a little higher, as two or three Lines, act a little leſs; and that ſome ſmall Impulſe may reach even five or ſix Lines; as it would happen if five or ſix Grains of Sand were contiguous to one another. *Vid. Fig.* 3. *Tab. ſeq.* As A E F D B falling upon the Rule G H, from a determinate Height, not being all in the ſame perpendicular Line, the two Grains D and B would ſtill a little contribute to the Impulſe of the firſt, though they would not act with their whole Weight, and all their Velocity not being in the ſame Line of Direction; the higheſt Grains A E F contribute likewiſe a little, and cauſe the Rule to be impell'd more ſtrongly than if only the Grains B and D were there.

Now Water being compos'd of an infinite Number of Corpuſcula or little Bodies, contiguous to one another, much leſs than the ſmalleſt Grains of Sand, that eaſily roll and ſlide againſt one another, a little Cylinder of Water, as G H, will have an Impulſe ſomething ſtronger than a leſſer one, as L H; becauſe there are more of theſe Corpuſcules in a direct Station one upon another in the Height of G H, than in the leſſer L H.

To proceed; the Air's Impulſe may be known by an Experiment made by a Machine, (*Fig.* 8. *Tab. ſeq.*) A B C D is a cylinderical Veſſel of Tin well ſolder'd, open at C D, and turn'd Bottom upwards into another Cylinder E F G H, in the Baſe of which is firſt a little Tube well ſolder'd, as L I, that goes into the inverted Cylinder, paſſing a little above the Water N K, that is, in the Cylinder E H, the upper Baſe is preſs'd by ſeveral Weights ſucceſſively

 to

to make the Cylinder deſcend, and at the ſame time to drive out the Air with Violence through the Tube I L; to the Bottom of which a Ballance is apply'd like that deſcrib'd *Fig.* 4. and upon one of the Ends of it different Weights are laid, to try the Force of the Air's Impulſe.

HENCE it follows, that if two Cylinders full of Air, of the ſame Height, having unequal Baſes, are preſs'd by equal Weights diſpers'd as the Cylinder A B C D; and having equal Holes or Apertures through which the Air is to paſs, the Weights which the Air ruſhing out will raiſe, will be to each other in a reciprocal Proportion of their Baſes; for let either of the two Cylinders A B C D, *a b c d*, be put into another Cylinder full of Water, as was explain'd in the foregoing Figure, and let the two Weights M and *m* be placed upon theſe unequal Cylinders, and be equal, and the Weights rais'd be P and *p*, namely, P by M, and *p* by *m*; foraſmuch as the Baſe G H is to the Aperture L, as the Weight M to the Weight P, rais'd by the Air going out of L, and as the Aperture E equal to L is to the Baſe *h g*; as the Weight *p*, rais'd by the Air going out at C, to the Weight M or *m*; the Proportion being found to be equal, the Baſe G H will be to the Baſe *h g*, as the Weight *p* to the Weight P. But if the Weights preſſing upon the Cylinders be proportionable to their Baſes, they will raiſe equal Weights by the Impulſe of the Air, which they will force out at equal Apertures; as if the Baſe G H be 24, and the Baſe *g h* 12, and the Weight M be 12 Pounds, and the Weight *m* 6; the Aperture L being 4, and *l* the ſame, the Weight P and *p* will be each 2 Pounds, which may be very eaſily proved.

THERE are three Propoſitions or Rules more that might be taken from *Marriotte*, to demonſtrate the Equilibrium and Impulſe of Water in three ſeveral Caſes, as by him ſet down, Diſcourſe III. Rule 3. p. 125. of the Tranſlation. The firſt is, that *Jet d' Eau's of equal Breadth iſſuing out at little Apertures, made at the Bottom of ſeveral Tubes full of Water, of different Heights, make an Equilibrium with Weights that are to each other* in the Proportion of the Heights *of thoſe* Tubes.

A SECOND is, *that Jet d' Eau's of equal Breadth and unequal Velocities, ſuſtain by their Impulſe Weights that are to* each other in a duplicate *Proportion of thoſe Velocities.*

A THIRD, which is indeed *Marriotte*'s ſecond, is, that *Water which ſpouts out at a round Hole from the Bottom of the Reſervatory, makes an Equilibrium by its Impulſe with a Weight equal to the Weight of a Cylinder of Water whoſe Baſe is that Hole, and*

whoſe

whoſe Height is from the Center of the Hole to *the upper Center of the Water.*

But as this will lengthen this Chapter beyond its due, and as they will in a great Meaſure be demonſtrated by the Propoſitions that go before, as well as this that follows, referring my Reader, for his farther Information of them, to the Book it ſelf; proceed we therefore to

PROPOSITION V.

Jets or Streams of the ſame Velocity, and different Apertures, ſuſtain by their Impulſe Weights that are to each other in a duplicate Ratio *of the Diameters of thoſe Apertures..*

Let two Surfaces A B and C D have two Apertures at E and F, (*Fig.* 9.) and let the two Spouts or Streams E N F M, paſs through theſe Holes, it is evident that the Surface of the Hole E is to the Surface of the Hole F, in a duplicate Proportion of the Diameter G H to the Diameter K L; and the Velocities being ſuppoſed equal, if the Diameter G H be twice as great as the Diameter K, there will be four times as many ſmall Particles of Water to impel in the Baſe G H, as in the Baſe K L; they will then produce a quadruple Effect, and if the Surfaces of the Spouts or Streams are reciprocal to the Heights of the Reſervoir or Stream from which they proceed.

From which it appears, that the Equilibrium, and conſequently the Impulſe of Air, Water, or any other Fluid, is in Proportion to its Height, and the Largeneſs of the Apertures, Streams or Spouts, through which, or from whence it proceeds, *and that the Spaces which Bodies go through from their Fall are in a* duplicate Ratio, *or as the Squares of the Times or Moments.* Which muſt ſerve as a Foundation to what we have to ſay on the Buſineſs of Hydraulicks or Water-Engines.

To reduce what has been ſaid in this Chapter to Practice, omitting the Uſes that might be drawn from the foregoing Propoſitions in Jets or Waters that ſpout upwards, I ſhall apply it chiefly to Mill-works, or the Effect it has on the Motion of Wheels in Hydraulicks or other Machines.

And ſince it is evident, from the foregoing Propoſitions and Experiments in general, that Water that iſſues from any Reſervatory, Mill-Pond, &c. receives *an additional Impulſe and Velocity, and acts in a duplicate Ratio, or as the Squares or Times of the Spaces through which they fall,* or in other Words, according to the different Heights from whence it begins ſuch Fall, it is or ought to be a

 certain

certain Direction to all Millwrights to raiſe the Head of Surfaces of the Water in Mill-Ponds, as high as poſſibly they can, even for an underſhot Mill, no leſs than four or five Feet.

And ſince it will appear alſo, from the following Chapter, that the Motion of Water is irregular, and that the middle Part of a Stream or River moves with more Celerity than the Bottom, becauſe that is often obſtructed by Weeds, Stones, and other Obſtacles, I ſay, this ſhould alſo inſtruct the induſtrious Millwright to fix the Trough through which the Water is to ſpout and lodge, on the Wheel at $\frac{2}{3}$, or rather $\frac{3}{4}$, of the Depth of the ſaid Mill-Pond, laying it ſloping in ſuch a Manner that it may lodge the Water with greateſt Advantage on the Pallats, (or which is more adviſable) the Boxes of the Wheels on which you are to throw it.

And ſince it is evident alſo, that *Jets or Spouts of Water do not* (on account of the great Number of Corpuſcules of which it is compos'd) *impel with the united Force of all its parts as other Bodies do*, this ought to inſtruct him to confine the Water in a ſtrong ſquare Trough of near the Width of the Box or Pallats, cover'd over ſtrongly at top with a Board of equal Thickneſs with the Trough, that ſo the Water may be reduc'd as near as poſſible to the Nature of a ſolid Body: For on the contrary, as may be ſaid from daily Experience, the great Reſiſtance of Air that is in the open Trough where the Wheel makes its Rotation, the Room there is on the Sides of the Pallats for the Water to run to waſte, and to have no Effect: And the Diſtance there is between the Bottom of the Mill-Pond and the Pallats of the Wheel, is ſuch, that the united Force of the Water is broken; its Strength in a great Meaſure loſt, and as much Water again waſted as if it were confin'd, which can't be of little Eſtimation in Mill-Ponds and Streams where Water is ſcarce, eſpecially in Summer Seaſons: But of this, more in the next Chapter.

CHAP.

CHAP. XIV.

Of the different Impulſe or Fluctuation of Water in a Mill-Pond or River (for the driving of Mill-Wheels) varied, according to the different Circumſtances which attend the Fall of it.

THE Irregularities in the Motion of a River may be infinitely varied, and Rules can't be exactly given to ſettle them; therefore ſetting aſide all Irregularities, we muſt examine the Courſe of Rivers, for unleſs the Laws of Motion be known in that Caſe, we have no certain Foundation for determining any, (notwithſtanding it is ſo effectually done in Waters that fall from a precipitate determinate Heighth). To compare this Velocity of Water, then, in open Rivers by Experiments, and to determinate them as near as poſſible, ſo as to know the Spaces which it paſſes thro' in a certain Time, and conſequently the Expence of Water, and Strength with which they ſtrike on the Pallats of a Wheel:

LET *Fig.* 10. *Tab. ſeq.* be a Quadrant divided into Degrees, with a Thread in the Center, that has at the other End a Ball P hanging, which is heavier than Water: Let the Ball hang within the running Water, whilſt you hold the Side C A of the Quadrant, in a vertical Poſition; the Ball, by the Motion of the Water, will be ſo far ſuſtain'd, that the Thread P C will make the Angle P C A, with the Side C A, which will ſerve to determine the Celerity of the Water running againſt the Ball.

THE Ball being at Reſt in the Water, is drawn by three Powers; by its Gravity it endeavours to deſcend vertically, by the Action of the Liquid it is carried in the Direction of the Motion of the Water; and, *Laſtly*, it is drawn by the Thread along P C. Draw the Triangle E F G, in which E F repreſents the vertical Line: Let F G make with that Line the Angle E F G, equal to the Angle, which

which the Direction of the Motion of the River makes with the vertical Line. *Laftly*, Let the Angle G E F be equal to the Angle P C A, the Sides of the Triangle E F G are parallel to the Directions of the three Powers above-mention'd; therefore the Powers are to one another, as thofe Sides.

If therefore E F exprefs the refpective Gravity of the Ball, F G will exprefs the Action of the Water on the Ball; and if you make feveral Experiments in different Places with the fame Ball, you muft draw fuch Triangles, the Side F remaining (which denotes the refpective Gravity of the Ball, that never changes) the Sides that are as F G will have the fame Proportions as the Actions of the Water on the Ball. But thofe are as the Squares of the Velocities of the Waters in the Places, in which the Experiments are made, for there is no Difference in Refpect of the Action of the Water on the Ball, whether the Ball be mov'd, and the Water at Reft, or on the contrary the Water be mov'd, and the Ball at Reft.

The Action of the Water againft the Ball may be compared with the Weight it has to the refpective Gravity of the Ball, as F G to E F.

But this Action is equal to the Refiftance which a Body fuffers, when it is mov'd through quiefcent Water, with the fame Celerity with which the flowing Water does now ftrike againft the Body, which is at Reft. By knowing the Weight, which is equal to the Refiftance, we know what Space could be run through in a given Time, with the Celerity with which the Body moves; therefore we fhall alfo here know what Space the Water can go through in a known Time, and fo likewife what Quantity of Water flows in a given Time, through a Place given in the Section of any River or Mill-Stream.

And here it is to be obferv'd, that the Determination of the Velocity of the Water, will not be exactly fettled, if the Experiment be made towards the Surface of the Water; becaufe there the Action of the Water upon the Globe is irregular.

This Celerity may be determin'd, by immerging in Water a Body which is but a little lighter than Water, and which fwimming at the Surface, does not float fo high above it, as to be affected by the Motion of the Wind; for as the fpecifick Gravities of the Water, and the Body fcarce differ at all, and that this Body may be look'd upon as wholly immers'd; it will move with the fame Celerity as the Water, and you may, by Help of a Pendulum, meafure the Time in which a Body runs through a certain Space that was meafur'd before:

before: When the Surface of the Water is agitated by the Wind, the Experiment will not ſucceed well, becauſe of the Motion of the Waves, which cauſe an Irregularity in the Motion of the Body.

It muſt be conſidered alſo, (according to *Marriotte*) that the Water of a River does not go equally faſt at its Surface, and its other Parts; for the Water near the Bottom is very much retarded, by meeting with Stones, Weeds, and other Inequalities.

To calculate this Difference in the Motion of Water in a River, our ingenious Author, as we have it, *Diſcourſe* III. *Page* 136. put two Balls of Wax faſtned to a Thread of a Foot long, into a little River, whoſe Motion was uniform; the one was loaded with little Stones within, to make its ſpecifick Gravity a little heavier than that of Water; ſo that when the two Balls were in the Water, the heavieſt ſtretch'd the Thread, and made the lighteſt ſink lower than it would have done, had it been alone; and by this Means its upper Part was almoſt upon a Level with the Surface of the Water; ſo that the Wind could have no Power over it.

It was always obſervable, that when the loweſt Ball ſtay'd behind, eſpecially in the Places where there were ſome Weeds at the Bottom of the Water, near which the lower Ball paſs'd, for this River was but about three Foot deep; but when theſe ſame Balls were put in a Place, where the Water meeting with ſome Obſtacle roſe a little, and afterwards took a more rapid Courſe, as is obſervable under Bridges, the lower Ball outwent the upper, which ſhews, that the Water in the Middle goes faſter than that of the Surface; which proceeds from this Cauſe, that the Water riſing a little higher, by Reaſon of the Obſtacle it met with, acquires a greater Velocity, by running down a ſteeper Declivity; and this Violence cauſes it to plunge, and go below that of the Surface, as if A B C D be the Courſe of the upper Water, and by an Obſtacle towards B, (*Fig.* 10. *Tab. ſeq.*) it riſes to the prick'd Line E F, it will run faſter along the ſteep Declivity E F C; and by the Velocity which it will have acquired at C, it will continue its Direction below C D as to G H, and conſequently it will go ſwifter at G and H, than at I and D: And thence it happens, that in moderate Rivers there are always great Cavities below Bridges, cauſed by building of Peers of Stone, or Piles of Wood to ſuſtain the ſame: Proofs of this are to be ſeen almoſt at all Places, but at none more than that of *London Bridge*, at the Flux and Reflux of the Tide, which being ſo well known, I need not enlarge upon it.

To explain this the better, let A B (*Fig.* 11. *Tab. ſeq.*) be an horizontal Line, and C D the Declivity of the Bottom of the River D E, the

the Water half a Foot Diſtance from the upper Part F G, both parallel to C B. Now, becauſe Water is ſuppos'd by ſome to be of a viſcous Nature, and its Parts a little join'd together, the Water D E will carry along with it that which is immediately above, with almoſt the ſame Velocity which it has it ſelf, and afterwards that which is at F G, which moving likewiſe of it ſelf, by Reaſon of its Inclination, goes a little faſter than the Water D E; which may be comprehended the better, if you ſuppoſe F L to be a Board ſwimming upon the Water, whoſe upper Part is in an Inclination parallel to C B, having a very round Ball upon it, for this Board being carried along by the Water, would carry the Ball along with it, which would of it ſelf alſo roll the Length of the Board to G, and conſequently its Velocity would be greater than that of the Board.

It has been further obſerv'd, from Weeds carried along by the Water, that thoſe within the Water, and neareſt the Bottom, being advanc'd farther than thoſe of the Surface, were ſoon overtaken, and left behind by the upper ones; and if upon the ſame Stream a Handful of great Sawings, or heavy Wood was caſt, that went ſome ſooner to the Bottom than others; it was always found, that thoſe that ſwam nearer to the Top, went before the others in a proportional Order, as they were more or leſs diſtant from the Bottom; from which Experiments it appears, that Rivers or Streams that run free by the upper Part of the Water, go faſter than that in the Middle, and the Middle faſter than that at the Bottom; but in thoſe that are conſtrain'd to paſs in a narrow Channel (being kept in on both Sides) the Middle goes ſwifter than the Surface, if there be but two or three Foot deeper Water. Thus far *Marriotte*. But the learned *Graveſande*, (upon the Foot of Sir *Iſaac Newton*'s Principles, and from his firſt Law of Nature, which relates to Motion (wherein he ſays, that all Bodies continue in their State of Reſt or Motion uniformly in a right Line, except ſo much as they are forced to change by Forces impreſs'd) aſſigns other Methods of Motion to Water running in Streams and Rivers, ſuppoſing Water to run in a regular Channel, without any ſenſible Friction, and that the Channel is terminated with plain Sides, that are parallel to one another, and vertical; and alſo, that the Bottom is a Plane, and inclin'd to the Horizon.

Let A E be the Channel, into which the Water runs, from a greater Receptacle or Head; and let the Water always remain in the ſame Heighth at the Head, ſo that the River may be in a permanent

manent State, the Water deſcends along an inclined Plain, is of the ſame Nature, and is accelerated for the ſame Reaſon as the Motion of a Body freely falling in the open Air, and of which we have treated in the foregoing Chapter, becauſe the ſame Quantity of Water flows through every Section, the Heighth of the Water, as you recede from the Head, is continually diminiſhed, and the Surface of the Water will acquire the Figure *i q s*.

To determine the Velocity of Water in different Places, let us ſuppoſe the Hollow of the Channel A D C B to be ſhut up with a Plane; if there be a Hole made in the Plane, the Water will ſpout the faſter through the Hole, as the Hole is more diſtant from the Surface of the Water *h i*, and the Water will have the ſame Celerity that a Body falling from the Surface of the Water to the Depth of the Hole below it would acquire, which ariſes from the Preſſure of the ſuperincumbent Air, Water, &c. as has been ſaid in the foregoing Chapter.

There is in like Manner the ſame Preſſure, that is, the ſame moving Force; when the Obſtacle at A C is taken away, then every Particle of the Water enters into the Channel, with the Celerity that a Body would acquire, in falling from the Surface of the Water, to the Depth of that Particle, and this Particle is mov'd along the inclin'd Plane in the Channel, with an accelerated Motion, and in the ſame Manner, as if vertically falling it had continued its Motion to the ſame Depth below the Surface of the Water in the Head of the River: So that if you draw the horizontal Line *i t*, the Particle at *r* will have the ſame Celerity as a Body falling the Length *i* C, and running down C *r* can acquire, which is the Celerity acquired by the Body in falling down *t r*.

On which Account it is, that the Celerity of a Particle may be every where meaſur'd, drawing from it a Perpendicular to the Horizontal Plane, which is conceived to run along the Water in the Head of the River, and the Velocity which a Body in the Fall from that Perpendicular will be, the Celerity of the Particle (which by the Rules laid down in the laſt Chapter) will be the greater, the higher or the longer the Perpendicular is.

From any Point, as *r* draw *r s* perpendicular to the Bottom of the River, which will meaſure the Heighth or Depth of the River, ſince *r s* is inclin'd to the Horizon; if from the ſeveral Points of that Line you draw perpendicular to it *i t*, they will be the ſhorter, the more diſtant they are from *r*, and the ſhorteſt of them all will be *ſ v*: Therefore the Celerity of the Particles in the Line *r s* are ſo much the leſs, the nearer they are to the Surface of the

River, *and the lower Water is*, in ſuch a Caſe, *mov'd faſter than the upper Water ; but yet the Celerities of thoſe Waters, as the River runs on, continually approach nearer and nearer to an Equality*; for the Squares of thoſe Celerities are as rt to sv, the Difference of which Lines, as you recede from the Head of the River, is continually leſſen'd, becauſe of the Line rs, which is continually diminiſh'd, as the Lines themſelves are lengthned. Now, as this obtains in the Squares, it will much more obtain in the Celerities themſelves, whoſe Difference therefore is diminiſh'd as they increaſe.

If the Inclination of the Bottom be chang'd at the Head of the River, ſo as to become yz, *and a greater Quantity of Water flows in the Channel, it will be higher every where in the River, but the Celerity of the Water is no where changed ;* for this Celerity does not depend upon the Heighth of the Water in the River, but (as has been demonſtrated) from the Diſtance of the moved Particle, from the Horizontal Plane of the Surface at the Head, continued over the ſaid Particle, which Diſtance is meaſur'd by the Perpendicular rt or sv: But theſe Lines are not chang'd by the Affluence of the Water, provided that the Water remains at the ſame Heighth in the Baſon or Head.

Let the upper Part of the Channel be ſtop'd up by any Obſtacle, as X, which deſcends a little Way below the Surface of the Water, the whole Water which comes cannot run through, therefore it muſt riſe up; but the Celerity of the Water below the Cataract is not encreas'd, and the Water that comes on is continually heap'd up; ſo that at laſt it muſt riſe ſo, as to flow over the Obſtacle, or the Banks of the River: But if the Banks be rais'd, and the Obſtacle continued, the Heighth of the Water would riſe above the Line it, but before that the Celerity of the Water cannot be increas'd ; in which Caſe the Heighth of all the Water in the Head will be increas'd ; for as we ſuppoſe the River in a permanent State, there muſt continually be as great a Supply of Water to the Head, as there runs from it down the Channel; but if leſs Water runs down, the Heighth muſt neceſſarily be increaſed in the Head, till the Celerity of the Water flowing under the Obſtacle be ſo much encreaſed, as that the ſame Quantity of Water ſhall run under the Obſtacle, which uſed to run in the open Channel before.

All theſe Things (as has been already ſaid) if we abſtract from the Irregularities, are true, and the leſs the Irregularities are, the more will the true Motions agree with what has been ſaid, concerning which, before any Judgment can be made, the Velocities

cities of Water by other Experiments muſt be compar'd, that theſe Velocities themſelves may be ſo determin'd, as to know the Spaces gone through in a certain Time, which is what has already been attempted, and will be more demonſtrable by what follows in this Chapter.

(With *Marriotte* then, Diſcourſe III. Rule 5. Page 133. of his *Hydroſtaticks*) to eſtimate the Force and Current of Water, againſt the Paddles, Pallats or Floats of a Mill, or any other Machine, you muſt know its Celerity or Velocity, and compare it with that of Water ſpouting from the Bottom of a Reſervatory. It is likewiſe neceſſary to know the ſpecifick Gravity of Water, with Reſpect to other Bodies, concerning which the following Obſervations have been made by that induſtrious Author.

A cubick Veſſel was prepared, made of Copper, one of whoſe Sides was ſix Inches, and conſequently its Content the eighth Part of a cubick Foot, which put into one of the Scales of a Balance, and a Weight equal to it in the other; afterwards it was fill'd very carefully with Water, through a little Hole, made towards an Angle in the upper Plate: And it was found, by ſeveral Trials, that this Water weighed 8 *l.* $\frac{3}{4}$. and conſequently that a cubick Foot of Water ought to weigh 70 Pounds, the *Paris* Muid or Barrel contains 8 cubick Feet, and every cubick Foot 36 Pints *French*, about ſo many Quarts *Engliſh*, when the Meaſure is ſo exact, as that the Water does not riſe above the Brims; but when it riſes as much above the Brims as it may, without running over; it contains only 35 Pints *French*, 35 Quarts *Engliſh*; and every one of theſe laſt Pints weighs 2 Pounds, and the other 2 Pounds wanting 7 Drams: The *Paris* Muid or Barrel contains 288 of theſe latter Pints, and 280 of the other: From thence it is known, that a Cylinder of Water a Foot in Height, and whoſe Baſe is a Foot in Diameter, weighs 55 *l.* (or with *Ozanan*, *Cap.* II. *Book* III. of his *Mechanicks* 54) Pounds, becauſe the Proportion of a Circle to the Square that circumſcribes it, is as 11 to 14: Now, as 14 is to 11, ſo are 70 Pounds to 55; whence you know, that a Cylinder a Foot high, and an Inch in Baſe, weighs 6 Ounces and a Dram very near (and according to *Ozanan* before mention'd, a cubick Inch weighs 3 Drams 3 Grains) for the 144 Part of 55 Pounds is 6 Ounces 1 $\frac{1}{9}$: Whereupon the following Experiments were made.

Having faſtned a little Boat, to another very great one, that was immovable in the Midſt of the Stream of a River, where it was very rapid, a Diſtance of 15 Foot was meaſur'd lengthwiſe

 on

on the little Boat; afterwards a little Piece of Wood was thrown out, or a Blade of Graſs 2 or 3 Foot from this little Boat, over-againſt the Place where the firſt Mark of the 15 Foot was; and by the Vibrations of a half ſecond Pendulum, was counted how many half Seconds it was in paſſing from one Mark to the other; if it paſs'd in 10 half Seconds, it was concluded, that in that Place the River went with a Velocity of 3 Foot in the Second.

After that there was Uſe made of an Axis, with two Rulers a-croſs them, in ſuch a Manner, that the Planes, in which they were, cut each other, at right Angles: At the End of theſe Rulers was fix'd a little thin ſquare Board, 6 Inches broad, that dipp'd perpendicularly into the Stream, till the Water roſe 2 or 3 Inches above it; and at the ſame Time, at the End of the other Rule, that was in a Horizontal Poſition, a Weight was put, at the ſame Diſtance from the Axis as the Middle of the Board, and increas'd or diminiſh'd it, till it made an *Equilibrium* with the Impulſe of the Water againſt the Pallet or little Board.

Several of theſe Experiments were made in that Part of the River, where the Stream was moſt rapid, and in other Places, where the Water did not go ſo faſt; and there was always found, pretty near the ſame Proportions, correſpondent to the Force of Water iſſuing to the Bottom of a Tube 12 Foot high; to make the Calculation of which, this is the Method.

It having been found, as before, that the moſt rapid Water went 3 Foot $\frac{1}{4}$ in a Second, and that there it ſuſtain'd by its Impulſe againſt the Pallet, 3 Pounds $\frac{1}{4}$, it was concluded, that the Jet, from the Bottom of a Reſervatory, 12 Foot in Heighth, goes out with a Velocity of 24 Foot in a Second, according to the Doctrine of *Gallileo*, before explain'd. This Velocity then is about 7 Times $\frac{1}{2}$ greater than that of the River, the Square 7 $\frac{1}{2}$ is 56 $\frac{1}{4}$; and conſequently if this Jet be of the ſame Breadth as the Pallet, it ought to ſuſtain a Weight about 56 Times greater. Now, 12 Cubick Feet of Water weighs 840 Pounds, the Quarter of which is 210 Pounds, which we take, becauſe the Pallet which is but half a Foot ſquare, and 12 Foot high, weighs 210; and if you divide 210 by 56, the Quotient will be 3 Pounds $\frac{1}{4}$, the Weight found by the Experiment.

Now, the Calculation of the Impulſe or Force of Wind againſt the Sails of a Windmill, may be made after the following Manner: It being premis'd before, that though Water be of a much denſer heavier Nature than Air, even as 24 to 1, yet to make Amends, its Velocity is alſo ſo much greater than Water, ſo that what

what it wants of Weight it has in Celerity or Impulſe, and that ejected Air, producing the ſame Effect by its Impulſe, as a *Jet d'Eau* of equal Breadth, muſt have a Velocity about 24 Times greater than that of Water: Let the following be the Experiment.

Take a Cylinderick Machine, with Rulers like that before deſcribed, (*Fig.* 5. *Tab. ſeq.*) Let A B repreſent its Axis, G H, is an Horizontal Ruler, that goes through the Axis of the Cylinder at right Angles: I L is another Ruler plac'd perpendicularly upon G H; again M N O P is a perpendicular Ruler, plac'd obliquely in an Angle of 45 Degrees, in Reſpect of the Ruler G R. Now, if you ſuppoſe a Jet of Water to ſtrike directly upon the Ruler I L, at the Point Q, ſo as to turn the Cylinder, according to the Order of the Letters *a b c d*, it will act with all its Force to ſuſtain the Weight R; but if another Jet equal to it ſtrike the Ruler *m o* directly at the Point S, which you ſuppoſe as far diſtant from the Axis as the Point Q, it cannot ſuſtain the Weight R, becauſe its Direction will not be parallel to the Direction of the Extremity of the Ruler I L; and it can only ſuſtain a Weight, that will be to the Weight R, as the Side of a Square to its Diagonal; and if the ſame Jet be parallel to the Axis A B, and ſtrikes at the ſame Point S, you muſt ſtill diminiſh the Weight R in the ſame Proportion, to make the *Equilibrium*, becauſe this Jet will ſtrike this Ruler obliquely in an Angle of 45 Degrees, and then R will have but half its Weight; for if A B C D, *Fig.* 6. *Tab. ſeq.* be a Square, the *Ratio* will be as that of A C to A B, and the ſecond as that of A B to A E, the Half of A C.

Now, the Wind that drives the Sails of a Wind-mill, ſtrikes againſt them obliquely; and if it meet every Sail in an Angle of 45 Degrees, no more of its Force would remain than in the Proportion of a Diagonal of a Square to its Side, for that Reaſon only; but if that Sail, which is oblique to the Axis, were ſo in the ſame Angle, this ſecond Cauſe would ſtill diminiſh the Force of the Wind in the ſame Proportion, as was ſaid before of the *Jet d' Eau*; and the total Diminution from theſe two Cauſes would be of half the Force of this Wind, when it ſtrikes againſt this Ruler, as I L, diſpos'd more at the Beginning, according to its Direction: So that, if its Total Force was ſo, it would be reduced to forty by theſe two Cauſes.

But Becauſe the Sail, whoſe Obliquity is 45 Dgrees, receives a leſs Breadth of the Wind, than when it is directly oppos'd to it, it ſtill receives a third Diminution in the ſame Ratio, as A C to A B, and the Total Diminution will be as A C to E F, or merely

as

as 80 to 28 $\frac{1}{4}$. But if the Obliquity of the Sail be N O, and the Angle made by A B and N O be of 60 Degrees, *Fig.* 5. *Tab. ſeq.* then the firſt Cauſe alone will diminiſh half the Force of the Wind, and reduce it from 80 to 40, and the two others together will reduce it from 40 to 31, or very near: Whence may be judg'd, that it is better that the Sails of a Wind-mill ſhould have the Obliquity of 60 Degrees, rather than that of 45, which they are generally made.

To illuſtrate this Matter yet further, and to calculate the Force of Wind that blows directly againſt the Sails of a Ship, the Velocity of the Wind muſt be found out, and which may be done by the letting down of a very light Feather, to be carried by the Wind from ſome fix'd Place, and obſerving the Time that it takes up in running through a certain Space, as 30 or 40 Foot.

Now, ſuppoſing Wind to go 24 Foot in a Second, it will go as faſt as a Jet that ſpouts from a Hole of 12 Foot below the Surface of its Reſervoir or Pond (as has been before obſerv'd) and becauſe the Wind ought to go 24 Times faſter than the Water, to produce the ſame Effect, it will perform no more than Water of an equal Breadth, that goes but one Foot in a Second, or than the Jet that goes 24, if the Breadth of the Wind be 24 Times greater in Diameter, or 576 Foot in Surface.

Now, a Jet half a Foot ſquare, coming from a Reſervoir or Mill-pond, can ſuſtain, (as was ſaid before) a Weight equal to the Weight of a ſquare Column of Water, whoſe Baſe is half a Foot ſquare, and whoſe Height is 12 Foot; and ſince a 6 Inch Cube (by the foregoing Tables) weighs 8 $\frac{1}{4}$, if you double this Height, it will be 17 Pounds $\frac{1}{2}$ for a ſquare Column of Water, of a Foot long, and half a Foot broad; and if it be 11 Foot long, 210 Pounds will be ſuſtain'd by a Jet half a Foot ſquare.

That the Wind then, moving with this Velocity, may ſuſtain the Weight of 210 Pounds, the Sail that impels it muſt be 24 broader and longer than half a Foot, that is to ſay, it muſt be 12 Foot broad, as well as long, or 6 Foot broad, and 24 Foot long, and then the Wind that goes 24 Foot in a ſecond, will ſuſtain 210 Pounds plac'd upon an horizontal Ruler, faſtned to the ſame Axis as the ſquare Sail of 12 Foot, at the ſame Diſtance from the Axis as the Middle of the Length of the Sail, which ought to be in a perpendicular Situation; but if the Wind goes but 12 Foot (which may be tried by the forementioned Experiment) it will ſupport but 52 Pounds and a Half, which is one Quarter of 210 Pounds.

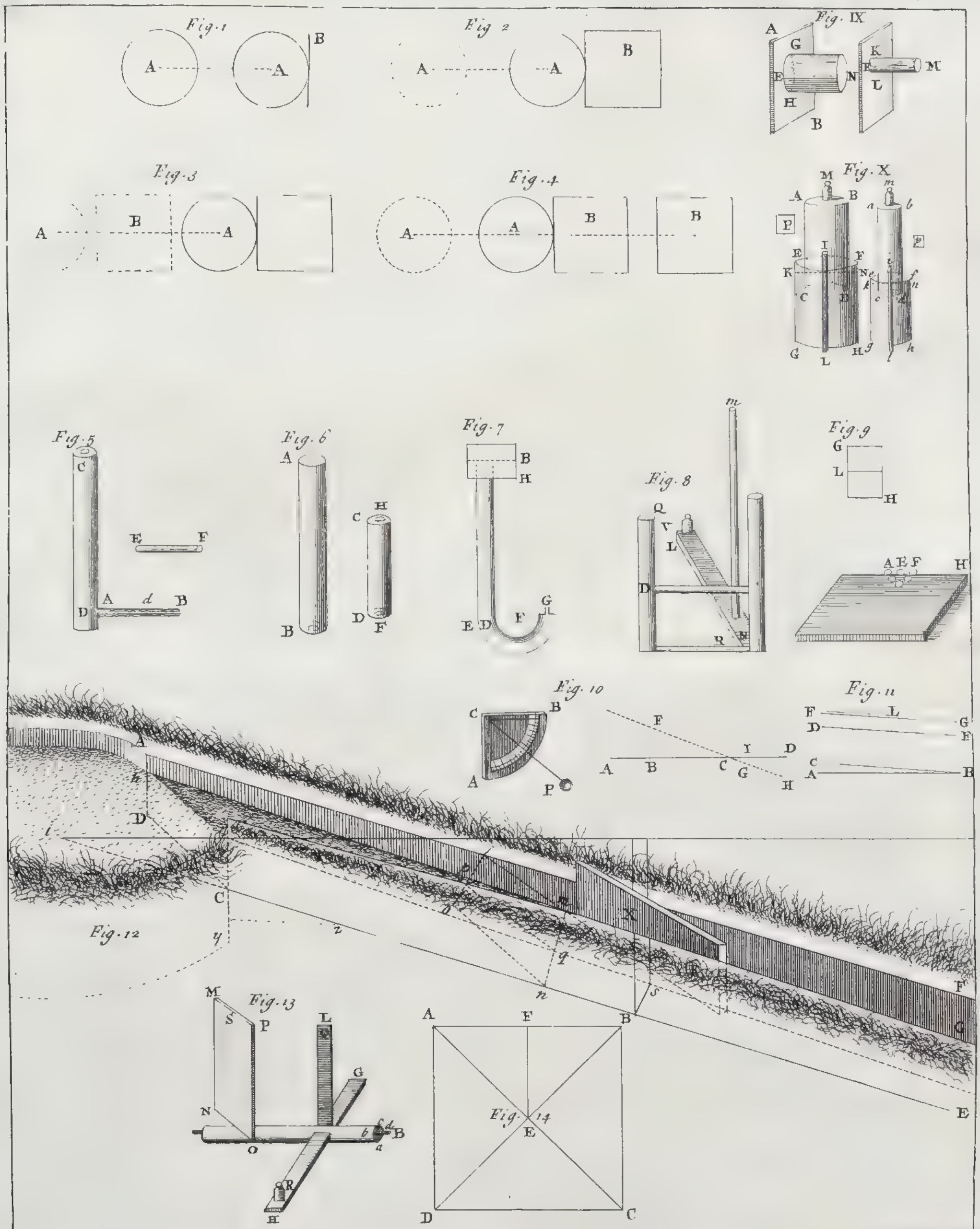


Fig. 1
Fig 2
Fig. IX
Fig. 3
Fig. 4
Fig. X
Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9
Fig. 10
Fig. 11
Fig. 12
Fig. 13
Fig. 14

Toms Sculpt

If you would know the Experiment in Miniature, you muſt make uſe of the Axis deſcrib'd, *(Fig. 5. Tab. ſeq.)* and take a Sail a Foot Broad, and a Foot long, whoſe Surface being a Foot will ſupport but 144th Part of 52 $\frac{1}{2}$, namely 5 Ounces $\frac{5}{8}$, if this Weight be of the ſame Diſtance from the Axis, in the Middle of this little Sail; but you muſt chuſe a Wind that goes 12 Foot in a ſecond.

From the following Method, ſays our oft-quoted *Marriotte*, may be eaſily calculated the different Forces of Water and Wind, by their Impulſe.

Suppose that each of the Sails is 30 Foot long, and 6 Foot broad, which produces 180 Foot; if the Wind goes but 12 Foot in a ſecond, it ſuſtains 5 Ounces $\frac{8}{9}$; when it impels a Sail of a Foot Surface; but if it impels 180 Foot in Surface, it will ſuſtain almoſt 66 Pounds, but you muſt take away $\frac{5}{8}$, by Reaſon of the triple Obliquity of the Impulſe (as was before prov'd): If the Obliquity be of 30 Degrees, there will remain 29 Pounds, and the four Sails will ſuſtain 100 Pounds; but the Diſtance of the Axis from the Middle of the Wheel, and that from the Middle of the Floats, to their Axis, is but 4 Foot.

Then, by this Cauſe, the Wind-mills will augment their Force in a Quintuple Proportion; and if the Cogg-wheel be two Foot in Diameter, the Force of the Wind-mill will be ten Times 100, and that of the Water-mills twice 466 Pounds, when the Wind goes 12 Foot in a ſecond, and the Stream of the Water 4 Foot, you may make the like Calculations for greater or leſſer Sails.

The naked Fan or Skeleton of the Sails of a Wind-mill are generally made 1 Foot from the Center of the Axis: It is 2 Foot from the ſaid Axis, or Center of the Axle-tree, to the Beginning of the Fan, and the Width of the Top of the naked Fann is 32 Foot, and 4 $\frac{1}{2}$ Foot long; ſo that the general Dimenſion or Square of the Sail is 32 Foot.

The laborious *Ozanan*, in his Treatiſe of ſimple and compound Engines, *Cap.* VII. *Page* 53. thus deſcribes an Engine, wherein the Wind is made Uſe of for a moving Power, (*viz.*) in a Wind-mill, where the Wind blowing round the Sails A B (when their Canvas is ſtretch'd (which in ſuch a Caſe are Leavers) cauſes the Axle C D to turn horizontally, and the Wheel E F vertically, whoſe Coggs take the Rounds of the Trundle.

CHAP. XV.

Of Mill-wheels for raising Water, &c. *their Dimensions, Strength, Position and the like; and also of the best Places for setting of Mills.*

WHAT has hitherto been set down, has chiefly had Relation to the Proportion, which the Perimeter of the Axis of a Wheel has to the Perimeter of the extreme Orb, to which any Force is join'd, or that the Semidiameter of the one has to the Semidiameter of the other, for their better Force in moving of great Weights; as also of the Power of multiplying Wheels, to that End and Purpose. But before I quit this Doctrine, of the Rowls or Wheels, in the Axis in *Peritrochio,* it may not be improper to subjoin some Speculations concerning these rotund Instruments, and moving Bodies, that our Calculations under this Head may be the more intelligible, and better understood.

IT is a common Observation, and that which *Aristotle,* in Question the 9th of his Mechanicks touches upon, *That large Wheels, Cylinders, and Spheres move with more Ease than small ones.* But as this is not always true, and as there will be Occasion to limit this extensive Doctrine, and to bring it into the best Light we can, let us reduce the Matter to its first Principle; and suppose that a Cylinder, such as *Aristotle* calls the Scytalis, or Roller, that is us'd in Gardens, or for the smoothing of any other Piece of Ground, such as is exhibited in *Fig. 6. Tab. seq.* If the Weight and Length of the Cylinder be equal, tho' the Diameter be more in the one than the other, it is plain, from every Day's Experience, that you may roll the larger with more Ease, than you do the lesser, because in the first Place, the Center of the large Cylinder is higher from the Plan of the Earth, than the Center or Axis of the lower, and consequently a Man or a Horse pulls at it with the greater Force, the whole Strain being Horizontal; but this I say is when the two Cylinders are made of diffe-

rent Materials, the one of Wood, and the other of Stone or Lead, of equal Length and equal Weight, though of different Diameters; and this is agreeable to that of the learned *Wallis, Cap.* 7. *Prop.* 1. of his Mechanicks, *Fig.* 258. where (treating of the Axis in *Peritrochio*) it is evident, that the Force of the Pully is nearly horizontal, at moſt not above 5 Degrees from it; for if the Rope at P were faſtened, in order to be wound up more towards B, the higher you go, the more Difficulty you would meet with, in drawing the Burden *n* R *s* on.

But, notwithſtanding this happens in ſmall Bodies, as Rollers, and other ſmaller Cylinders, and lower Wheels; yet if we conſider the Reſiſtance of Air, it is manifeſt, that the greater Circumference a Wheel is of, ſo much the larger Portion of Air it has to contend with, and conſequently the greater is the Friction or Reſiſtance, and that large Wheels move with more Difficulty than ſmall ones; and this ſeems to me to be one Reaſon why they have chang'd many of their large underſhot Wheels, in their cloathing Mills about *Braintree* in *Eſſex*, and other Places, for thoſe that are ſmaller; ſince though the Weight of Water is to Air, as 800 is to 1, yet where there is but little Water, and the Wheel of ſuch a vaſt Magnitude, 800 Weight added to the other Weight or Offices the Wheel is to perform, is a great Incumbrance: However, where there is Water enough, and to ſpare, and where the Aſcent is very high, that you force your Water, and conſequently the Weight great (certain enough it is) that the larger your Wheel is, the greater Weight it will raiſe, and the higher it will throw your Water; and where the Strength of the Stream is capable of overballancing the Reſiſtance, and exterior Preſſure of Air, the Uſe of the Mills before ſpoke of, not requiring ſo great Strength as thoſe do, that are employ'd in raiſing great Quantities of Water, 'tis there the latter are to be choſe, and prefer'd.

But again, in Relation to Wheels, and their different Sizes and Poſitions, it is very certain, that overſhot ones are beſt, where you have but little Water, as being drove by a much leſs Quantity thereof, than underſhot Wheels are; for, as has been obſerv'd before, in the Crane or Tread-wheel, where a Man is endeavouring to climb up, if the Man's Weight were at (A), inſtead of (*a*), and touch'd the Orbit of the Tangent Line directly, rather than obliquely, the Wheel would move with the more Velocity, and conſequently elevate the more Weight; how much more when the Water falls into the Top of the Wheel at C, where, by undoubted Ex-

periments, it has ſix times the Force, and will conſequently raiſe ſix times the Weight, than when it falls in at (*a*); and as a farther Conſequence, ſtill a ſixth Part of the Water will ſerve for the driving an overſhot Wheel, that does an underſhot; and the true Reaſon why there are not more overſhot Wheels, is that in moſt Places, eſpecially in flattiſh Meadows, the Mill-Pond or Head of Water cannot be well rais'd above 4 or 5 Foot high at moſt; and in thoſe Places likewiſe there are very great Quantities of Water, ſufficient for the ſtrongeſt underſhot Wheel, whilſt in the mean Time, no overſhot Wheel can be reckoned of any Account under 7 or 8 Foot Diameter, if they be 10, 15, 20 the better: In the Mines of *Durham*, at *Lumley* Caſtle, I have ſeen an Overſhot of 28 Feet Diameter.

And this leads me to what I have been all along aiming at; I mean the Poſition of Mills, the Diameter of their Wheels, and the like.

Now, as to the Poſition of Mills, it is certain they ſhould be as near the Place (to which you throw your Water) as poſſible; but the main Conſideration is, how you ſhall place it ſo, as that you may have a good Mill-pool or Head, and alſo an eaſy Paſſage for your Mill-Tail, or Back-water; ſo that generally ſpeaking, a Mill ſhould be plac'd upon a midling Hill, near a Hollow, that the waſt Water may paſs off the quicker, ſo as to ſave Labour and Expence; or if the Ground be a little lowiſh, as it is in all low Meadow-land, you muſt bank up the Sides to what Height you can: But thus far Nature and common Experience directs, that you ſhould forſake the low Ground, and keep as cloſe as you can to the Sides of that which lies higher.

It is as well known alſo, that the farther you go back, the higher may you make your Bank, and Mill-pond, which ſhould be took, where the Owner can, half a Mile, a Mile, or two or three.

But as every Mill-wright, or his Maſter, can not have ſuch a Command, but muſt be content with what the Riſe of his own Land will allow, in (perhaps) 2, 3, 4, or 500 Yards (for he muſt not penn up the Water, to the Damage of other People, that lye behind him): By the Rules before laid down, he muſt take the Deſcent; and if he finds he can make his Cutt, or Mill-pool 7 or 8 Foot high, why then he may venture at an overſhot Wheel, if he has but little Water; but if he has a great deal, he need not ſtrain ſo hard, as to attempt at ſo great a Height, but be content with 4, 5, or 6 Foot Diameter (ſeldom more, as he pleaſes) and now the Poſition of the Mills, the Diameter of the Wheels, and the like being ſettled, thus proceed to the Work and Frame of the Wheel, *&c.* it ſelf.

A. N.

NOTES on BOOK II. CHAP. 10.

Of the Air-Pump. Fig. 8. Plate 9.

IT having been my Method in two or three Chapters going before, to add ſome few Notes, for the better Illuſtration of the Chapters foregoing; I take the ſame Liberty in this, in order to the fuller Explanation of the wonderful Properties of Elaſtick Air, as it is diſcovered by the Air-Pump, tho' ſomething is in the Text already hinted: And firſt of all, I ſhall give a Deſcription of the Air-Pump, as it is contriv'd by *Graveſande* in his *Mathematical Elements of Natural Philoſophy:* And this I do, for a further Demonſtration of the Elaſtick Power of Air, which is largely treated of in ſome of the Chapters going before; becauſe the Elaſticity of Air is explained in the Conſtruction and Uſes of a Machine, by which the Air may be drawn out of any Veſſel; and this Machine is call'd an Air-Pump, and is made ſeveral Ways: The chief Part in all of them is a Barrel, or hollow Cylinder of Metal, bored ſmooth, and poliſhed in the Inſide; in this Barrel muſt move a Piſton, that fills its Bore ſo exactly as to let no Air ſlip by. This Piſton is thruſt down cloſe to the Bottom of the Barrel, and then raiſed up in ſuch Manner, as to exclude all the Air from the Cavity of the Cylinder or Barrel; if this Cavity communicates with any Veſſel by means of a Pipe at the Bottom of the Barrel, the Air in the Veſſel will expand itſelf, and part of it will enter into the Barrel, ſo that the Air in the Barrel, and in the Veſſel will have the ſame Denſity. At the ſhutting up of the Communication between the Veſſel and Barrel, and letting the Air out of the Barrel, apply the Piſton cloſe to the Bottom. If you raiſe the Piſton a ſecond Time, and open the Communication between the Barrel and Veſſel abovementioned, the Denſity of the Air in the Veſſel will again be diminiſhed; and repeating the Motion of the Piſton, the Air in the Veſſel will be reduced to the leaſt Denſity. Yet all the Air can never be exhauſted by this Method; for at every Stroke the Air does ſo expand it ſelf, as to have the ſame Denſity in the Barrel as in the Veſſel, in which laſt therefore there is always a little Air left.

ALL Air-Pumps have in common the Parts above deſcribed, but they differ in ſeveral other Things. *Firſt*, The Communion between the Receiver to be exhauſted, and the Cylinder or Barrel, is opened and ſhut different Ways. *Secondly*, There are different Ways of getting the Air out of the Cylinder or Barrel, when the

the Piston is brought to the Bottom. *Thirdly*, The Pistons differ in different Pumps. *Fourthly*, The Position of the Cylinder is not the same in all Pumps. *Fifthly*, There are different Contrivances for moving the Piston.

There are often two Barrels; in one of which the Piston is raised, when it is depress'd in the other. The Pump describ'd *Fig*. 8. *Plate* 9. has two Brass Barrels C, C, of 2 Inches Diameter, and about 5 Inches high.

In these Barrels the Pistons move, one of which descends, while the other rises, which Motion is communicated to them by the Wheel at Top, which is moved by the Handle M M, *Fig*. 9. *Plate* 9. fix'd to the Axis *a*. The angular Motion of the Wheel, is the eighth Part of a Circle, by which in a less Wheel there is produc'd an angular Motion of 120 Degrees. This lesser Wheel is fixed to a third Wheel, by Means of which the Pistons are immediately moved; they make a Stroke of 3 Inches and a half.

The Contrivance of the Piston is much the same as in the Pumps which they use in *England*; tho' we think that we have made ours more perfect, by some Alterations in them.

The Glass is to be exhausted, or set upon the round Plate L L; they communicate with the Barrels, by Means of a Pipe, one End of which is at D, and which solder'd to the lower Side of the Plate, the Continuation of this Tube is seen at E E; there are two Cocks in it, E E, between the Cocks is fixed the Pipe *l*, *l*, which communicates with the Cylinders C, C.

When the Air is exhausted, one of the Cocks above-mention'd serves to shut the Communication between the Receiver (so the Glasses are call'd from which the Air is to be pumped out) and the Barrels; the other Cock serves to let the Air in again, and to cut off the Communication with the Mercurial Gage.

This Mercurial Gage could not be conveniently represented in this Figure; it serves to determine what Quantity of Air is drawn out of the Receiver, as also what Quantity of Air remains in it; it is likewise of Use for measuring the solid Contents of the Receivers, which ought to be exactly known in several Experiments; our Gage differs from the common Gages in several Respects.

A little Cylinder, with a Screw upon it, is often screwed into the Plate at D, for applying a Globe to be exhausted to the Pump.

In the Middle of the Plate L L, there is a Hole, which is shut up with a Screw; but sometimes it serves for joining several Machines to the Plate.

By this Means also, there is often applied to the Pump a cylindrick Box, full of Leathers soak'd in Wax, thro' the Center of which a Brass Wire passes, which may be moved by the Help of a Handle, so as to communicate Motion into a Place void of Air; the Box has a Cover, which enters into it with a Screw, for pressing the Leathers together, and to prevent the entering in, or escaping out of the Air; such a Box or Collar of Leathers, is often joined to the Cover which is laid over the Recipients, as may be seen in *Fig*. 10. *Plate* 9.

When the Receivers are laid upon the Plate L, L, or when the Receivers are stoped with Covers, or when the Screws are joined to the Machine, and in general, when the Air is to be hinder'd from running in, we make use of Wax, which is soften'd by mixing as much Oil and Water to it as is found necessary.

The Last Account of an Air-Pump, which I shall produce, is that contriv'd by the late Ingenious Mr. Hawksbee, *and which he made use of in all his* Physico-Mechanical Experiments, *being esteemed the best in its Kind that is extant.*

This Pump, which is delineated *Fig*. 11. *Plate* 9, consists of two Brass Barrels or Cylinders, as represented by *a a a a*, twelve Inches in height, and two their Diameters within. The Suckers, or *Emboli*, are raised and depress'd by turning the

the Handle at the Center *f* backward and forward. The Winch is faſten'd to a Spindle, that paſſes through a Lanthorn, whoſe Pins perform the Office of Cogs: For in its Motion they lay hold on the Teeth of the Racks *c c c c*, and ſo, reciprocally, as one is depreſs'd, the other is elevated: By which Means the Valves, which are made of limber Bladder, and fix'd on the upper Part of each *Embolus*, as well as at the Bottom of the foremention'd Cylinders, perform their Offices mutually of exhauſting and diſcharging the ſame Air taken from the Recipient on the Plate of the Pump. And when the Recipient comes to be pretty well exhauſted of its contain'd Air, the Preſſure of the outward Air on the deſcending Sucker is nearly ſo great, that the Power requir'd to raiſe the other is very little more than what ſurmounts the Friction of the moving Parts; which renders this Pump preferable to all others: For in the working of them, the nearer they approach to a *Vacuum*, the greater is their Labour. But this that I am now deſcribing (under the ſame Circumſtances) is quite contrary.

The Bottom of the Barrels are placed in a Braſs Diſh, repreſented by *d d*, whoſe Sides are about two Inches high, and is on purpoſe to put Water in, to keep the Leather Collars (on which the Braſs Cylinders ſtand) moiſt, whereby the Air is prevented from inſinuating into the Cylinders of thoſe Parts.

The Cylinders are ſcrew'd down on the ſame by the Nuts *e e e e*, which force the Frontiſpiece *f f* down on them, thro' which the two Pillars *g g g g* paſs.

The Pillars have an Iron belonging to each of them, and paſs from them in the Form of a Swan's Neck, decypher'd by *g g*, which Irons are faſten'd to the hinder Part of the Frame, for their better Security from ſhaking.

From between the two Braſs Barrels ariſes a Braſs hollow Wire, *h h h h*, which hath a Communication with each of them, by means of a perforated Piece of Braſs which lies along horizontally from one to the other.

The upper End of this hollow Wire is faſten'd to another Piece of perforated Braſs, which ſcrews on underneath the Plate *i i i i*, which is ten Inches over, and has a Braſs Rim ſolder'd on it, to prevent the ſhedding of Water; for which there is Occaſion in ſeveral Experiments. Between the Middle and the Side of this Plate ariſes a ſmall Pipe *k*, about an Inch and an half in height, through which, into the foremention'd hollow Wire, paſſes all the Air into the Barrels, as it is taken from the exhauſting Receiver. Upon the Plate of the Pump is always laid a wet Leather, on which the Recipients are placed: This wet Leather prevents the Air getting into the Glaſſes, whoſe Edges are truly ground, and is of uſe for that Purpoſe beyond any Cement whatſoever; and not only ſecures it from the Air's Ingreſs that Way, but by the Uſe of it we can make ſeveral Experiments in the ſame Time they could formerly make one, without any Daubing or Difficulty.

Another Excellency in this Pump is, the Contrivance of the Gage denoted by *l l l l*; which Gage is a Glaſs Tube about 34 Inches long, and is ſo placed, that it cannot eaſily receive Damage, and is altogether out of the Way of any thing that is experimented on the Pump. Its lower Orifice is plung'd in a Glaſs of Mercury deſcrib'd by *m m*, on the Surface of which is laid a piece of Cork with a Hole in the middle of the Glaſs Tube to paſs thro': On this Cork is plac'd a Board made of Box-Wood, about an Inch in Breadth, and groov'd in the middle to receive the foremention'd Glaſs Tube, which is looſely loop'd on to the ſame by two Braſs Loops, that it may have the Liberty of riſing and falling, as the Mercury aſcends or deſcends in the Gage.

To the upper part of this Tube is cemented a Braſs Head, which Braſs Head fits into the forementioned perforated Braſs Piece that is ſcrew'd on under the Plate, and has a Communication as well with the Recipient on the ſame, as with the hollow Braſs Wire *h h h h* paſſing between the two Barrels.

The Box Board is graduated into Inches and Quarters, from the Surface of the Quickfilver to 28 Inches high: From thence 'tis divided into Tenths of Inches. From this Gage the Degrees of Rarefaction in any Experiment are at all times moft nicely to be obferved.

The Air-Cock *n*, which lets in the Air, is likewife a Screw on the fame foremention'd perforated Brafs, in which the upper parts of the Gage and hollow Wire are inferted: *o o o o* reprefents a Receiver ftanding on the Plate of the Pump, on whofe upper part *pp*, through a Box of Collars of Leather, paffes a Slip Wire, whofe Office is to take up, let fall, or fufpend any Thing at any determinate Height, in the Receiver, without the Air's Infinuation.

Book II. Page 194.

The Preffure of Air depends upon its Height.

THAT I might finifh what I have to add, as to the Weight and Gravitation of Air, I have added this Note out of *Marriotte*, which is, I humbly conceive, amongft the moft curious of all his Experiments.

The Weight of Air (fays he) is ftill farther prov'd by an Experiment curious enough: Take a Glafs Bottle A B (*Fig.* 4. *Tab.* 6.) in which there is an Hole made of 2 or 3 Lines, as at C; put a Glafs Tube as D E about two Lines Diameter into the Neck of the Bottle, as at G, and cement them together with a Mixture of Wax and Turpentine, or with Pitch, fo that the Air can't get between them; then laying the Bottle along, through the Aperture C, you fill it with Water, and fill likewife at the fame time the Tube E D, keeping the End D clofe ftopp'd; and when you place the Bottle in its perpendicular Situation, the Water in the Tube will defcend to E, and as much will go out through the Hole C, if the Extremity E of the Tube anfwers in Height to the Middle of the Hole C; but if the Tube reaches down below the Hole as far as I, the Water will ceafe running, when the Tube is empty as far as E, and the Bottle will remain full of Water up to the cemented Neck towards G; but if the End of the Tube be a little higher than the Top of the Hole C, as at L, and it be two or three Lines broad, then you will fee the Air go out through this open End, and rife again to the Top of the Bottle, and at the fame time the Water will go out through the Hole C, till there be none left above the Point C.

Thefe Effects are explained in the following Manner.

The External Air preffing towards the Hole C by its Weight, endeavours to pufh up the Water, which endeavours by its Weight to get out, and the Air which is above the Tube E D preffes likewife, and acts by its Gravity upon the Water contain'd in the Tube, which being join'd to the Weight of that Water, muft overpoife the Weight of the Air which acts at C, which caufes the Water in that Tube to defcend

deſcend to E, and then the Air preſſing on one Side at E, and on the other at C, jointly ſuſtain the Water in the Bottle from E and C, up to A and H, and it wou'd even ſuſtain it, though the Height C H were of 30 Feet, provided the End of the Tube were below the Bottom of the Hole C; but when the Tube deſcends no lower than L, then the Water from L to E, join'd to the Weight of the Air which preſſes upon L, will overpoiſe the Air at C, and the Water will go out through the Hole C, whilſt the Air deſcending from D to L, and entering Drop by Drop into the Water through the open End L, riſes above the Surface of the Water which is below the Neck of the Bottle; but if you incline the Bottle in ſuch Manner that the Point L and the Middle of the Aperture C may be in the ſame horizontal Line, you will ſee half a Drop of the Air get below the Point L, but not ſeparate from the reſt, unleſs you raiſe the End L a little higher.

WHEN you have let ſome Air into the Bottle, ſo that the Surface of the Water is at N O, and dilate that Air by heating it with your Hand, you will force out ſome Drops of Water at C, though the End of the Tube be below this Hole, and the Water will deſcend as to *p q*, but if you let the Air grow cold again, you will ſee for ſome time Bubbles of Air enter in at C; becauſe the Air which had deſcended as far as P Q, contracting it ſelf within the Space which it took up at firſt from N O at A H, and there being no Water to fill up the Space N O P Q, the Air muſt come in from without, through the Hole C.

WATER has no ſenſible Elaſticity, and makes an *Equilibrium* with other Bodies only by its Weight or Impulſe: The firſt *Equilibrium* that is remarkable in Water, with reſpect to Air, is, that being reduc'd to very ſmall Particles, it becomes lighter than Air, and riſes in a Vapour, as was before obſerved. We can't tell how ſmall ſuch a Particle of Water muſt be to make an *Equilibrium* with the Air near the Earth, becauſe thoſe Particles, which are a little lighter or a little heavier than Air, are inviſible when they are ſeparate from each other. 'Tis very difficult likewiſe to find out the Reaſon of their Riſe, for it can't be that they are mix'd with Air, becauſe they would ſtill weigh more than pure Air; 'tis not by Reaſon of Heat, becauſe we ſee Vapours ariſe from very cold Water; 'tis probable then that in the Air there are very fine Pores, void of all heavy Matter, into which theſe fine Particles of Water may inſinuate themſelves, and riſe therein, and into which the groſſer Particles can't enter.

THESE ſmall Particles make an *Equilibrium* with the Air at about a League or two Leagues Diſtance from the Earth, where they remain a long Time ſuſpended, till many of them being join'd together they become heavier; and when the Air is very much rarefied, they fall to the Earth.

THIS is further illuſtrated by an Experiment in the Air-Pump; for when you have pump'd out ſome part of the Air, you ſee the Recipient grow dull by the Fall of the Vapours, which the Air, by reaſon of its too great Rarefaction, being no longer able to ſuſtain, they fall in fine little Drops upon the Glaſs which contains them.

IN Places where there are great Water-Falls, you ſee Vapours perpetually ariſe, which are nothing but Particles of Water broken by their Impulſe: And when a Soap Bubble comes to break, one Part of the Water, of which it conſiſts, falls, and the reſt, being reduc'd to very fine Particles, aſcends in a Vapour.

RULE I.

For the Equilibrium *of Water by its Weight.*

Water being in one or ſeveral Veſſels, that communicate with each other, has its upper Parts always upon an equal Level that is, at equal Diſtances from the Center of the Earth.

The EXPLANATION. *Fig. 5 Plate 6.*

LET A G H C be a recurve Tube, whoſe Diameter is equal in all its Parts; pour

ſome

ſome Water into it at the End A, and it will riſe to the ſame Height in the other Leg of the Tube; that is, if D E be an Horizontal Line, and the Water in the Leg A G, riſes as far as D, it will riſe in the other as far as E, and there continue when you have ceas'd pouring, and the Water is at reſt.

For, firſt, if the Legs be of equal Breadth, and equally inclin'd to the Horizon, there being an Equality in every Reſpect on both Sides, the Water can't remain at the unequal Heights A and F, becauſe the Weight of the Water A G will be greater than that of the Water H F; and conſequently in deſcending it can take to it ſelf a greater Quantity of Motion, than it will give to the other in aſcending, ſince they will have equal Velocities and the ſame Directions.

Therefore by the univerſal Principle, the Water can't be at reſt, unleſs it be at the ſame Height in the two Legs. But if you ſtop the End C with your Finger, before you pour in the Water at A, and fill the Leg A G with Water up to A, the other will be empty, and no Water, or very little at moſt, will riſe into it; becauſe the Air takes up the Place, if the Leg A G be not above two or three Feet in Height; then if you take off your Finger, the Water in the Leg A G will deſcend, and Part of it will go into the other Leg, and riſe as high as E, whilſt the other falls as low as N, and afterwards it will riſe to D, and fall again as low as M; till at length, after ſeveral Vibrations, it will be at reſt on both Sides at an equal Height as I F.

When in this Experiment the Water begins to deſcend from the Leg A to go into the other, it accelerates its Motion till it be at an equal Height in the two Legs, as at I F, where the *Equilibrium* ought to be; and afterwards its Velocity gradually diminiſhes till it be got to the Points N and E; it deſcends again after the ſame Manner, accelerating its Motion from the Height E, till it be paſt the aforeſaid Level I F, and diminiſhing it till one of the Heights be at D, and the other at M; and theſe Vibrations will continue till the Water be at reſt at I F, juſt as a Pendulum accelerates its Motion, till it comes to the Point of Reſt, which it diminiſhes in re-aſcending from that Point; and at length, after ſeveral Vibrations, ſtands ſtill.

The ſame Thing will happen in a Veſſel, as A B C D (*Fig.* 6. *Plate* 6.) fill'd with Water up to E F; for if by pouring in Water at F, you raiſe it as high as G, it will not remain in that Situation, after you have left off pouring in other Water: For the Weight of the Water G K H C, being greater than that of the Water K I L H, (L H and H C being ſuppos'd equal,) it will for the ſame Reaſons overpower it, and raiſe Water towards I K, and at the ſame time the upper Surface G K being inclin'd, the Water will move from G towards I; and for the ſame Reaſon, the Water E B L I will riſe likewiſe: And at laſt, after ſeveral Vibrations, the upper Surface of the Water will be upon a Level. Hence what happens, when a Stone is thrown into a ſtanding Water, as at N, (*Fig.* 7. *Tab.* 6.) may be explained; for the Stone raiſing the Water round it in a Circular Wave, whoſe Elevation is repreſented by O and P, it can't remain in that Poſition; but the Part O will move towards L, and in its Motion will impel and raiſe the Water next to it as R, which will likewiſe impel and raiſe that which follows it, in ſuch manner, that the Water rais'd at O will ſeem to move as far as L.

The ſame Thing will happen to that Part of the Water rais'd at P, and by this Means a circular Wave will ariſe, which receding from the Point N, will grow larger and larger, till it reach the Banks L and M, if they be not too far diſtant; and in its Reflection from thence, a new circular Wave will be form'd, which will advance on both Sides towards N, continually enlarging its Circumference, and leſſening his Height, till the whole Surface of the Water be got to a Level.

Let us ſuppoſe now the two Legs (*Fig.* 8. *Tab.* 6.) of unequal Diameters, as A B C D, the Water will be at the Height E F, which is the ſame in both Legs and the

the Column AB; AB will not overpoiſe the Column CF; for let the Baſe BG, which is ſuppoſed Square, be ſixteen times greater than the Baſe C, and if it be poſſible, let the Water deſcend from E to I, and aſcend on the other Side to D; that which is ſuppos'd to deſcend from E to I, will be equal to the Water contain'd betwixt F and D, and the two little Cylinders FD, EI, will have their Heights reciprocally as their Baſes: Then as 16 is to 1, ſo is the Height FD to EI: Now the Cylinder EB being ſixteen times greater than the Cylinder CF, will weigh ſixteen times as much: But the Space paſs'd through in the ſame Time by the little Cylinder, will be likewiſe ſixteen times greater than the Space paſs'd through by the great Cylinder, and their Directions are the ſame, both being perpendicular: Then their Velocities muſt have been reciprocally as their Weights, and they muſt have had an equal Quantity of Motion, which is impoſſible; for by the univerſal Principle, theſe Cylinders ought to make an *Equilibrium*; and one can't make the other move, becauſe they are diſpos'd to take an equal Quantity of Motion, according to the ſame Direction.

If you pour Water into the narrow Tube till it be as high as D, it can't remain there in a State of Reſt, till the other Leg be fill'd up to A: For let the Height FD be an Inch, and its Baſe an Inch, and the Water BE, 160 Cubic Inches, and FC 10 Inches, then the whole Column of Water CD will be 11 Cubic Inches. If then the whole Column CD falls an Inch, the Water EB will riſe $\frac{1}{16}$ of of an Inch; *viz.* the Height EL, and the Space EL will be the Meaſure of the Velocity of the Water BE, as DF is that of the Water CD: Now 160 multiply'd by $\frac{1}{16}$, gives 10 for the Quantity of Motion, and 11 multiply'd by 1 gives 11; then the Quantity of Motion of the Water DC will be greater than that of the Water BE, or which is the ſame Thing, the Velocity of the Water in the ſmall Tube will be greater in Proportion to the Velocity of the Water in the great Tube, than the Weight of this latter is to the Weight of the former; and by the univerſal Principle the Water in the ſmall Tube muſt deſcend. The ſame Conſequences may be drawn with reſpect to other unequal Heights, till the two Surfaces of the Water in each Leg be upon a Level, nor will the Water be at reſt, till it be at the ſame Height in both.

The Water AG may be ſtill further conſidered, as divided, according to its Length, into ſixteen little ſquare Columns, each of which may be ſuppoſed equal to the ſmall ſquare Column CD; and becauſe none of theſe ſmall Columns can riſe higher, or fall lower than the others, the ſame may be concluded of the little Column CD, though it be not contiguous to them.

Hence it follows, that if you put a floating Body upon the Water in the Leg AB, and the Weight of the Body be equal to that of the Water contain'd in the Height AE, when that Water is pour'd off, the Water in the little Leg will ſtill remain at the Height CD, and there will be an *Equilibrium* betwixt the Column CD, and the Water BE, joined to the Weight of the Floating Body, for the Reaſons above-mentioned.

When the narrow Leg is very ſmall, as about half or one third of a Line in Diameter, the Water will riſe an Inch or two higher in that, than in the other Leg; which likewiſe happens when you dip a Glaſs Tube, whoſe Diameter is leſs than one Quarter of a Line, into Water, for it will riſe therein to the ſame Height of an Inch or two above the other Parts of the Water's Surface, and the whole Quantity of Water that riſes above the Level, in Tubes that are very ſmall, or in ſuch as are only moderately ſo, as about a Line, or half a Line in Diameter, is ſenſibly equal to a great Drop of Water, that being fix'd to ſome Body hangs at it without falling.

The ſame Effect may be ſeen in the Experiment of the Bottle before mention'd (*Fig.* 4. *Tab.* 6.); for if the Tube be very ſmall, as about half a Line in Diameter, the Wa-

ter will fall in it no lower than L, about an Inch above E, and then this particular Caufe of Adhefion refifts the Effort of the Air, which is above the Water in the Tube; and the narrower the Tube is, the higher the Point L will be.

SOME attribute the Caufe of this Effect to the Weight of the Air, which acts with its full Force upon the Water in the large Tube, and can't act fo well upon that in the fmall one; but this can't be the Reafon: For if you dip fuch a Tube in *Mercury*, it will not rife fo high in it as the Level of the reft of the *Mercury*; and yet in this Cafe the Weight of the Air ought to have the fame Effect upon the *Mercury* that it has upon the Water: Whereas, if one of thefe narrow Tubes, that is not above half an Inch high, be dipp'd in Water, the Water will rife in it to the Top, altho' the Air has then no Difficulty to infinuate it felf. And for a further Proof, if the Sides of the Tube be thick, or if it has been fome time without Wetting, it contracts a certain greafy Subftance, which the Water can't fix upon; and then the Water will not rife above the Level, though the fuppos'd Defect of the Weight of the Air continues the fame without Alteration.

THIS Effect then is to be explain'd by the fame Reafons, that make Water in a Veffel of Wood rife above a Line and an half towards the Sides with a little Concavity, which caufes Two Drops of Water to join together, when they touch each other, of which Reafons I have fpoken at large in the firft Difcourfe.

A furprizing Effect of the *Equilibrium* of Water may be feen in the following Experiment: Take a Veffel or Butt of Water, about two or three Foot broad, as A B C D, (*Fig.* 9. *Tab.* 6.) make an Hole at the Top, as at E, and fix a Tube therein of an Inch Bore, fo clofely join'd with Hurds and Pitch, or other glutinous Matter, that no Air can get into it, and let this narrow Tube, *viz.* E F be 12 or 15 Inches high; fill the Veffel with Water by fome Holes made in the Top, and afterwards ftopp'd up, and put thereon Seven or Eight Hundred Pound Weight which will fink that Top to a Concav'ty, as A M D; if you put a white Mark on the outfide of the Tube, as at the Point H, and at the Side a little higher a Rule or Index, as I L plac'd in a neighbouring Wall; and fix'd in fuch Manner, that it may remain immoveable; as you pour Water by little and little into the narrow Tube E F, you will fee, when it comes to be full, that the Top A M D, together with the 800 Pound Weight that it bears, will be rais'd not only to its firft Situation A E D, but that it will take even a Convex Figure, and be rais'd in the Middle as much above the Point E, as the Point M was below it before; which you will fee by obferving the white Mark H rife by Degrees above the Ruler I L, with which you may meafure the Difference. And if the Tube be longer, the Elevation of the Weight will ftill be greater: Whence you may conclude, that the fmall Quantity of Water in the Tube has as much Force to raife this great Weight, and pufh up the Top of the Veffel to a Convexity, as if the Tube were of the fame Bore or Breadth as the Veffel. This Effect is prov'd by the fame Reafons beforementioned, concerning the Water in the fmall Tube C D, which will raife the Water in the Tube B A (*Fig.* 8.) when 'tis no higher than E, tho' it fhould weigh a thoufand times as much: For the Velocity which the Water in the fmall Tube F E (*Fig.* 9. *Tab.* 6.) will take in its Defcent, will be to the Top of the Veffel in afcending, as the Surface of this Top is to the Surface of the Water in the Tube; that is to fay, if the Tube be an Inch in Diameter, and this Top of the Veffel 30 Inches, the Surface of the Top will be 900 times greater than the upper Surface of the Water in the Tube: Then if the Water in the Tube defcends an Inch, that which touches the Top of the Veffel, will rife but $\frac{1}{900}$ Part of an Inch. And confequently, if the Water in the Tube weighs a Pound, it will make an *Equilibrium* with 900 Pounds, then it will raife the 800 Pounds that are on the Top of the

Veffel

Veſſel; with the little Quantity of Water that is above A E D; but for the greater Exactneſs of the Calculation, and of the Manner of Reaſoning, you muſt ſuppoſe that the whole Top of the Veſſel riſes all at once.

When one of the Legs of a Syphon is inclin'd, and the other perpendicular, both being pretty near of the ſame Diameter, Water in that Syphon will likewiſe be upon a Level; (*Vid. Fig.* 10. *Tab.* 6.) for let the Syphon A B C be plac'd in ſuch Manner, that the Leg A B may be perpendicular, and C B inclin'd to the Horizon, it is manifeſt that the Weight of the Water in D B will be to the Weight of the Water in E B, as the Bulk D B is to the Bulk E B; but if E D be an Horizontal Line, the Sum of the Force, which the Water E B has to deſcend, will be to that which it wou'd have if it fell perpendicularly, as the Length E B is to the Length D B: Therefore it will make an *Equilibrium* with the Water D B, whoſe Direction is perpendicular, according to the univerſal Principle; for the Spaces paſs'd through in the ſame Time by both Quantities of Water in each of theſe Tubes, according to their natural Direction towards the Center of the Earth, will be in a reciprocal Proportion of their Weights; that is, as the Weight of E B is to that of D B, and conſequently the Water E B will not overpoiſe the Water B D; the greater Friction in the long Tube may cauſe ſome Difference, and a little retard the Motion of the Water along the inclin'd Plane E B; but altho' either of theſe Tubes ſhould be larger than the other, that wou'd not hinder the *Equilibrium* for the Reaſons above-mention'd.

When a Syphon has one of its Legs much larger than the other, as in the 21ſt *Figure*, ſtop the Mouth of the little Leg with yoer Finger, and afterwards fill the great one with Water, then take off your Finger all at once, and you will find that the firſt Motion of the whole Column of Water A B is retarded, by Reaſon of the Difficulty which it meets with in its Paſſage at G; but the Motion through F C is much faſter in its Beginning, than when the two Legs are of equal Bore; whence it happens, that if you pour a little Water into the Leg F C, till the Tube of Conjunction B C be full, and after you have ſtopp'd the Mouth F with your Thumb, you fill A B, the other Part of the Syphon, up to the Horizontal Line E D, and then take off your Thumb all at once, the Water will riſe higher than D, even up to F, becauſe the Water in the great Leg, though it deſcends ſlowly, yet it makes that in the little one riſe very faſt, and all the Water being in Motion, in order to come to an *Equilibrium*, it ſtill moves (after it has got thither) by its acquired Velocity, as appear'd in the uniform Syphon; which cauſes the Water in the great Leg to deſcend ſtill, and make the other riſe Three or Four Inches above D from whence it deſcends again, and after ſome Vibrations ſtands at laſt at the ſame Height, in both Legs below E F; and though the Tube A B ſhould be full before you take off your Thumb, the Water would ſtill ſpout up Three or Four Inches higher than F, provided the Leg A B be much larger than C D; for then the falling and riſing in this large Leg will be very ſmall, and almoſt inſenſible. Theſe are the Experiments that have been made concerning it.

I took a Veſſel made of Tin, as A B C D, (*Fig.* 12. *Tab.* 6.) of Four Inches Diameter, which had a Tube E F, to which I join'd a bended Glaſs Tube, as F G H; I fill'd the Veſſel and the Tube E F, after I had ſtopp'd the Mouth at H with my Thumb, to hinder the Air from getting out; and when I had taken off my Thumb, the Water ſpouted up to I, Three Inches higher than the Surface of the Water D A; but when the Glaſs Tube reach'd Five or Six Inches higner than A D, the Water roſe in it Four Inches higher than H, from whence it fell again, and at length came to an *Equilibrium.* The ſame Experiment was made in a Tube L E F, whoſe Diameter was

B equa'

equal throughout, G H being ſtill narrower than L E F, and the Water ſpouted up above the Point H, juſt as it did when the Veſſel A D was above E F: Now in theſe Caſes the Water begins to riſe pretty faſt at G, and afterwards riſes a little faſter when the Water L E has acquired ſome Motion. But this Velocity in the Paſſage from G to H begins to diminiſh, when the Water in each Tube or Leg is come to an *Equilibrium*, that is, to the Height at which it ought to ſtand in both the Tubes, as to the Horizontal Line K M. But if you put different Liquors in the two Tubes, the lighteſt will be higher than the other, in a reciprocal Proportion of their Weights. The Rules of which are as follow.

A Rule for the Equilibrium *of different Liquors by their Weight.*

THERE are two Sorts of Gravity in Bodies here to be conſidered; one proceeding from the Maſs or Bulk of the Body, as a Cubic Foot of Wood weighs more than a Cubic Inch of the ſame Kind of Wood; the other proceeding from the Denſity of Bodies, or from ſome other Reaſon by which one Body weighs more than another of equal Bulk, as a Cubic Inch of Gold weighs more than a Cubic Inch of Iron; this latter we call *Specific Gravity*; thus the Specific Gravity of Water is greater than that of Oil; the Gravity of the Air, in which the Body is weigh'd, is not here conſider'd, though in Strictneſs it ought to be.

LET there be an *Equilibrium* of Water at the Height D E, in the Syphon A B C (*Fig.* 13. *Tab.* 6.); pour ſome Oil gently into the Tube C D, to the Height C, then you will ſee the Water deſcend below E, and riſe about D in the other Tube; let E F be the Meaſure of the Deſcent, and D G of the Elevation, and draw the Horizontal Line F H; then the Oil F C will be to the Water H G reciprocally, as the Specific Gravity of the Water is to that of the Oil; for the Water F B will make an *Equilibrium* with the Water B H, then the Oil F C will make an *Equilibrium* with the Water H G; now that the whole ſhould remain in this Situation, 'tis neceſſary that the Parts H and F ſhould be equally preſs'd, from the above-mention'd Principle: Then the Quantity of Oil F C will weigh as much upon F, as the Water H G upon H. The ſame Effect will appear in Mercury and Water; for if you put Mercury into the Syhon A B C to the Height D E, and then pour in Water gently at C, inclining the Syphon a little at firſt, to hinder the Water's mixing with the Mercury, and let the Water riſe up to C, and the Mercury to I, the Water will then fall to the Horizonal Line K L; and the Water K C, together with the Mercury K B, will make an *Equilibrium* with the Mercury B I; and as the ſpecific Gravity of Mercury is to that of Water, ſo reciprocally will the Height K C be to the Height L I, and by this Means it will be eaſy to determine the Specific Gravity of Liquors with Reſpect to each other; for if Mercury weighs fourteen times more than Water, K C will be fourteen times longer than L I.

AND thus I have trac'd the *Equilibrium*, or Weight of Air in Reſpect to Water: As to the Balance of Wood, Wax, and other Metals, with which *Mariotte* ges on, it will be needleſs to inſert it in this Place.

The End of the Notes of the ſecond Book,

apparently complete ca 12/52
25.6.84
BQIRH.

SA86-781
VΔS

coll. 2.5.

2 vols
R00